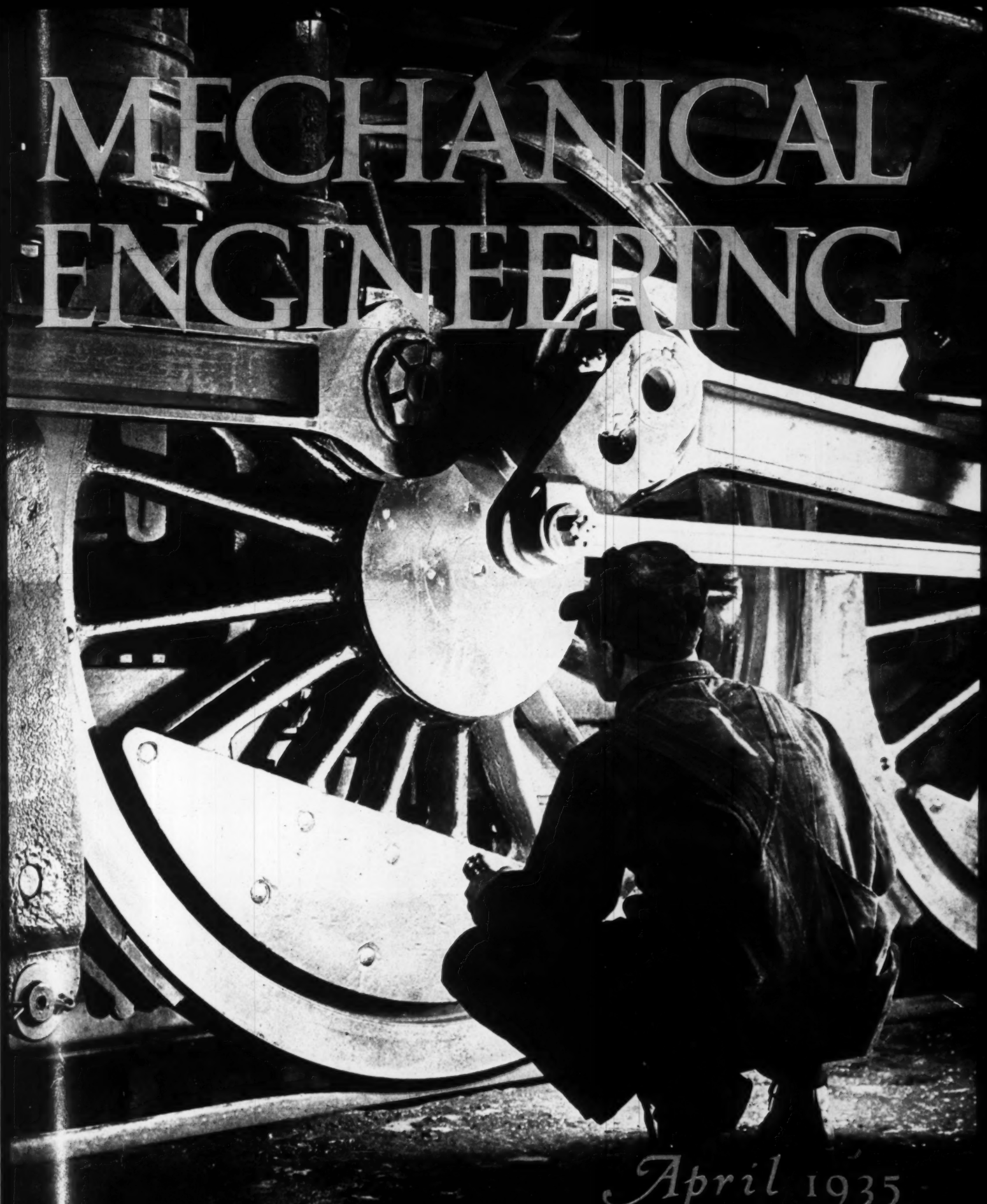
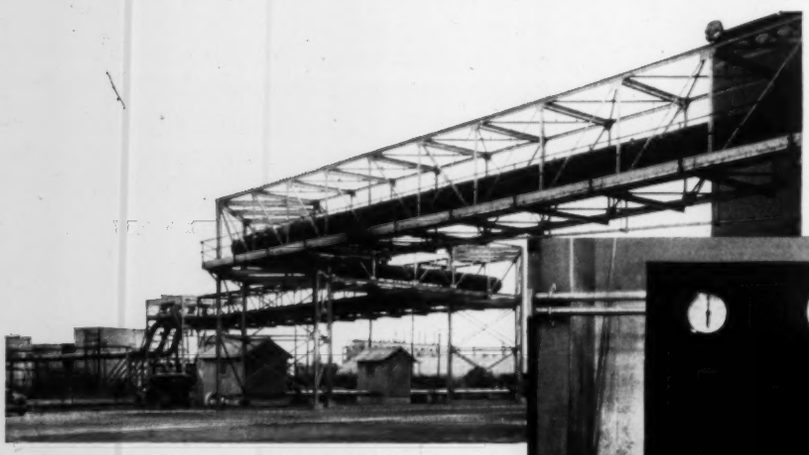
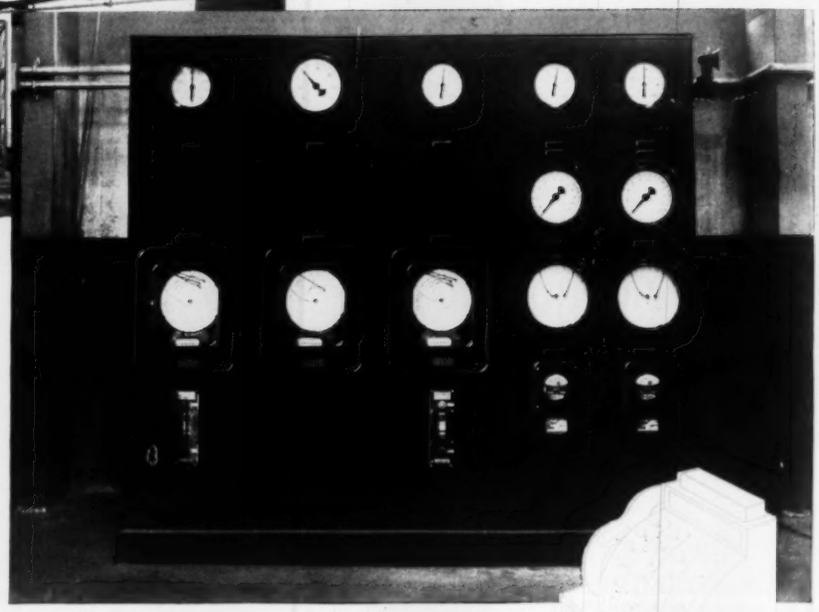
# MECHANICAL ENGINEERING



April 1935



*Twenty-four inch overhead pipe lines carrying steam from generating plant to oil refinery.*



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# MECHANICAL ENGINEERING

*Published by The American Society of Mechanical Engineers*

VOLUME 57 NUMBER 4

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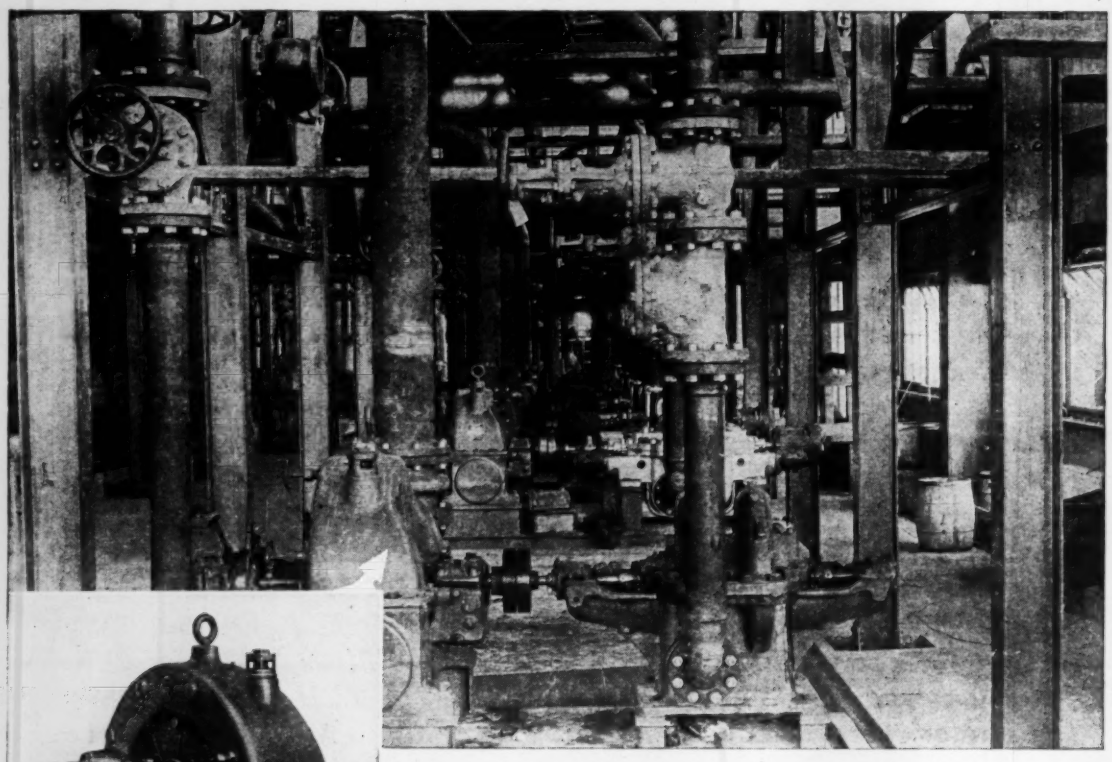

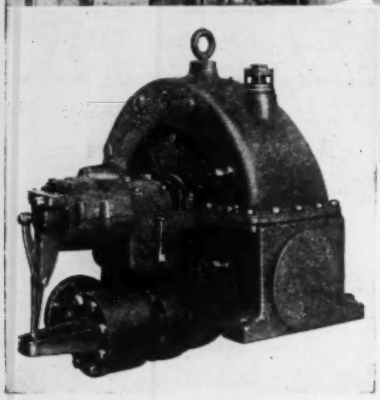

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VOLUME 57
No. 4

# MECHANICAL ENGINEERING

APRIL
1935

GEORGE A. STETSON, *Editor*

## *The Frontispiece*

IN CONSIDERING the ordered beauty of complex air currents as revealed in our "frontispiece," one is led to wish that some intellectual stroboscopy might be devised by which the eternal flux of life itself could be caught forever in a frame without destroying the dynamical process that establishes it. The Heracliteans more than 2000 years ago summed up their philosophy in the simple formula, "everything flows," and since that time attempts to capture the best that life has had to offer have too frequently necessitated stopping it in some favorable phase. Stagnation has proved so different from the dynamic vitality which it supplanted that a study of it has not been particularly useful. Were Mr. Edgerton and his colleagues able to provide us with some stroboscopic means by which a study of life could be carried on without stopping the vital machine, engineering would indeed contribute mightily to the cause of philosophy.

## *The Kay Gyroplane*

PARTICULAR attention is called to an abstract, on page 244 of the current issue, on the Kay gyroplane. The original machine was flown in 1932 in Scotland. A much improved unit has now been finished at Eastleigh, England, at the works of Oddin Bradbury & Cull and is said to be of the highest standard of construction. The machine is of interest not so much because of its performance, about which comparatively little is as yet known, but because it provides an indication of the possibilities of development in aeronautical machinery other than the standard airplane. While the latter has reached a high state of development and shows further possibilities of improvement by such means, as, for example, wing slots, flaps, and variable-pitch propellers, it is fairly clear that it is not likely to overcome certain limitations of which the most important are inability to land on restricted fields and the necessity of ample room for take-off. The autogiro was the first to show that these limitations are not inherent in air vehicles and that both the take-off and the landing can be performed in restricted spaces. Even as we go to press a dispatch from London reports that de la Cierva has succeeded in getting one of his autogiros off the ground without a forward run.

Time alone will show whether the Kay gyroplane has carried us further along toward the ideal flying machine than has the autogiro to which the gyroplane bears a clear relationship. It does, however, introduce what is claimed to be a new feature, namely, control of the rotor-blade incidence over a certain range while in the air. If the mechanical complications involved in the new operation are not sufficiently great to overcome its usefulness, an interesting performance may be expected from the new member of the family of heavier-than-air flying machines, that is as yet, unfortunately, by no means numerous.

## *Men and Manners*

SOME time ago we called attention to a booklet by Mary Perin Barker containing the subject matter of her discussion with the engineering students at the Newark Technical College on good manners. Mrs. Barker received so many inquiries about the pamphlet that John Wiley and Sons, Inc., has published it for sale at the modest sum of fifteen cents per copy. The present title is "The Technique of Good Manners, a Handbook for College Men."

Dean Kimball contributed the introductory note to the pamphlet. He has told us that his suggestion for a title "Are You Housebroken?" was turned down by the publishers. Admittedly, young men, like puppies, have to go through a trying period of growing up and becoming civilized. While some have more natural and environmental advantages than others, all can profit from better manners, as observation of any group of normal men will abundantly testify. But if it is too late to teach the old dog new tricks, perhaps there is some particularly ignorant puppy who would profit by Mrs. Barker's very practical pamphlet.

## *Biomechanics*

THE connection between mechanical engineering and the strength of the fibrous tissues of sheep and other animals, reported on page 217, may be remote, and the utility of bits of fact about the physical characteristics of these tissues may be negligible to engineers, yet Watt did not hesitate to look to dray horses for a unit with which to measure the power of his engines,

nor have aeronautical designers ignored the study of birds. What seems most significant, however, in the brief paper by Doctors Gratz and Blackberg, published in this issue, is the successful rapprochement of the engineering and biological sciences in the work which is reported.

The paper indicates how the experience and technique of one field of research may be carried over into another, and how the rich and abundant atmosphere of a university may provide a favorable environment for quests for knowledge. The authors give grateful acknowledgment of their indebtedness to many groups and individuals; for the clinical work to the Department of Orthopedic Surgery of the New York Post Graduate Hospital, Columbia University; for the research work to the Departments of Surgery and Pharmacology of the College of Physicians and Surgeons, Columbia University, and for valuable cooperation to the Departments of Physiology and Anatomy; for engineering advice and assistance to the Engineering Societies Library, the A.S.M.E., the Bell Telephone Laboratories, and the Department of Mechanical Engineering, Columbia University. An architect is said to have aided the authors in drawing charts and checking data. As a result of the work, a new approach to certain surgical problems, now christened "biomechanical," is being developed. As an example, therefore, of extensive cooperation of groups of workers who normally consider their fields of interest widely divergent, the paper has significance and is published for the possibilities it suggests.

## *Open the Doors*

IT SEEMS to us that the Allis-Chalmers Company did a splendid service to the people of Milwaukee and to themselves by opening their shops some time ago and permitting the families of their workmen and all others interested, 30,000 of them, to see what manner of places they were and what manner of work was done. Perhaps we misjudge human nature, but it seems as though it will be hard for the people of Milwaukee to judge this company unsympathetically and uncritically after such an experience. The wonder is that so few industrial plants attempt this kind of public-relations activity.

By the building up of great industrial establishments we have removed from the people at large a personal knowledge of what goes on in the industrial world. Modern youth does not, like that of Longfellow's village blacksmith days, "look in at the open door." The textile mill, the carpenter shop, the boot and harness maker, the sawmill, and the grist mill, familiar at one time, have become too big for boys to look at—and boys are as curious about these things today as they ever were. Most modern plants are a joy to good housekeepers and a pride to owners and workers. The mystery that is built up around them by their closed doors provides opportunities for foes of the industrial system to picture all sorts of barbarities as going on within them. Why not open the doors, and ask the neighbors in to see our work places?

Some time ago an earnest student of social conditions wrote about the workers in a certain factory who were handcuffed to their machines. The demon foreman thus kept them chained like galley slaves to their oars, while the inhuman machine set the pace for their uninterrupted labors. Investigation showed that this chaining was a device used to safeguard the hands of the worker. Connected with the mechanism of the press were chains which snatched the hand of the unwary from the danger zone between the dies when the press was in operation. Thus was an industrial devil exorcised by a knowledge of what it was all about. Probably much of the mawkish sentiment and undeserved pity for the worker would vanish as quickly if people who have never been in an industrial plant, but who assert so definitely what terrible places they are, were to visit some of them and see for themselves what they are really like.

## *Economics Reviews*

IN APPROACHING, on page 235, a review of a book on economics written by an engineer, Professor Freeman warns us against the dangers of oversimplification. Each of us in the fields to which we have given study will issue a similar warning before attempting an explanation, yet in the discussion of engineering problems we like to feel that we have more positive, and possibly simpler, laws to deal with than seem to operate in the fields of economics and social relationships. This apparent advantage of the practical man engaged in the familiar field of applied science is likely to evoke in him a distrust of philosophers who dabble in the more subtle mysteries. And yet that stage of scientific development in which, for example, the behavior of gases is discovered to be so perfectly and simply described by $PV = MRT$ is ultimately replaced by a concern for the deviations from the law in real gases. We want to believe in the honest simplicity of a rational universe because we have assurance when we think we understand. However, to abandon a search for truth because of the dangers of oversimplification or the despair of discovering a neat formulation cannot be easily justified, and engineers should be the last to attempt the justification.

Engineers have, in fact, frequently entered the free-for-all arena of economic and political discussion and having done so they assume responsibilities. Presumably they reach a wider audience among engineers than elsewhere, and presumably their training makes their method of approach and their deductions more plausible to engineers than to others. Recognizing this state of affairs, the Management Division of The American Society of Mechanical Engineers, through whose efforts most of the treatments of economic subjects published in MECHANICAL ENGINEERING have been made available, has secured the cooperation of the Department

of Economics of the Massachusetts Institute of Technology in providing brief discussions by the economists of that department on current literature in this field written by, or closely affecting, engineers. The first of these is published this month and has been written by Professor Freeman, acting head of the Department. The intention is to bring the experience of trained thinkers in this field to bear upon fundamental questions. Readers of MECHANICAL ENGINEERING are indebted to the Management Division and to the Department of Economics at M.I.T. for these reviews and discussions.

The book referred to in Professor Freeman's article is the work of an engineer, one of whose previous books was also reviewed in MECHANICAL ENGINEERING.

## *Coal-Dust Diesel Engine*

HISTORICALLY the coal-dust Diesel engine is not new, as the original Diesel was to have been run on this fuel. It lay dormant, however, until a few years ago when it was revived by the German engineer, Pawlikowski. It is now becoming fairly clear just where, if at all, this type will fit in.

As matters stand now the oil companies do not need to worry much about the potential loss of the Diesel fuel market due to the development of the coal-dust engine. Both the efficiency and the output per unit of a given size of the engine will be somewhat lower with coal dust than with oil. Moreover, the coal-dust engine will run more slowly than one burning oil fuel, so that it may be said that while possibly suited for stationary plants, the coal-dust engine is not likely to become extensively used in vehicular transportation.

From an engineering point of view the greatest difficulty in the development of the coal-dust Diesel lay in the comparatively slow ignition and combustion of the fuel-air mixture when injected in a conventional way. This is said to have been obviated by the introduction of a fore-chamber, the purpose of which is to gasify some of the fuel and thus accelerate its combustion in the main chamber. From tests reported from Germany it would appear that the use of this device has materially improved the operation of the engine. Unquestionably, however, it will substantially increase the cost of the engine, and as a matter of fact it would appear that the first cost of a coal-dust engine in any event is going to be higher than that of an oil-fired one.

The greatest difficulty in operation lies in the fact that while practically complete combustion may be obtained in the oil engine, the fuel supply to the coal-dust engine contains non-combustible ashes. It is stated that the wear due to the presence of these ashes is not very serious where special materials are used for moving parts, and it is also said that the presence of the ashes does not greatly interfere with lubrication. However, this is a weak point and one likely to create trouble, although the use of special materials for machine parts is in itself not objectionable unless their cost becomes exorbitant.

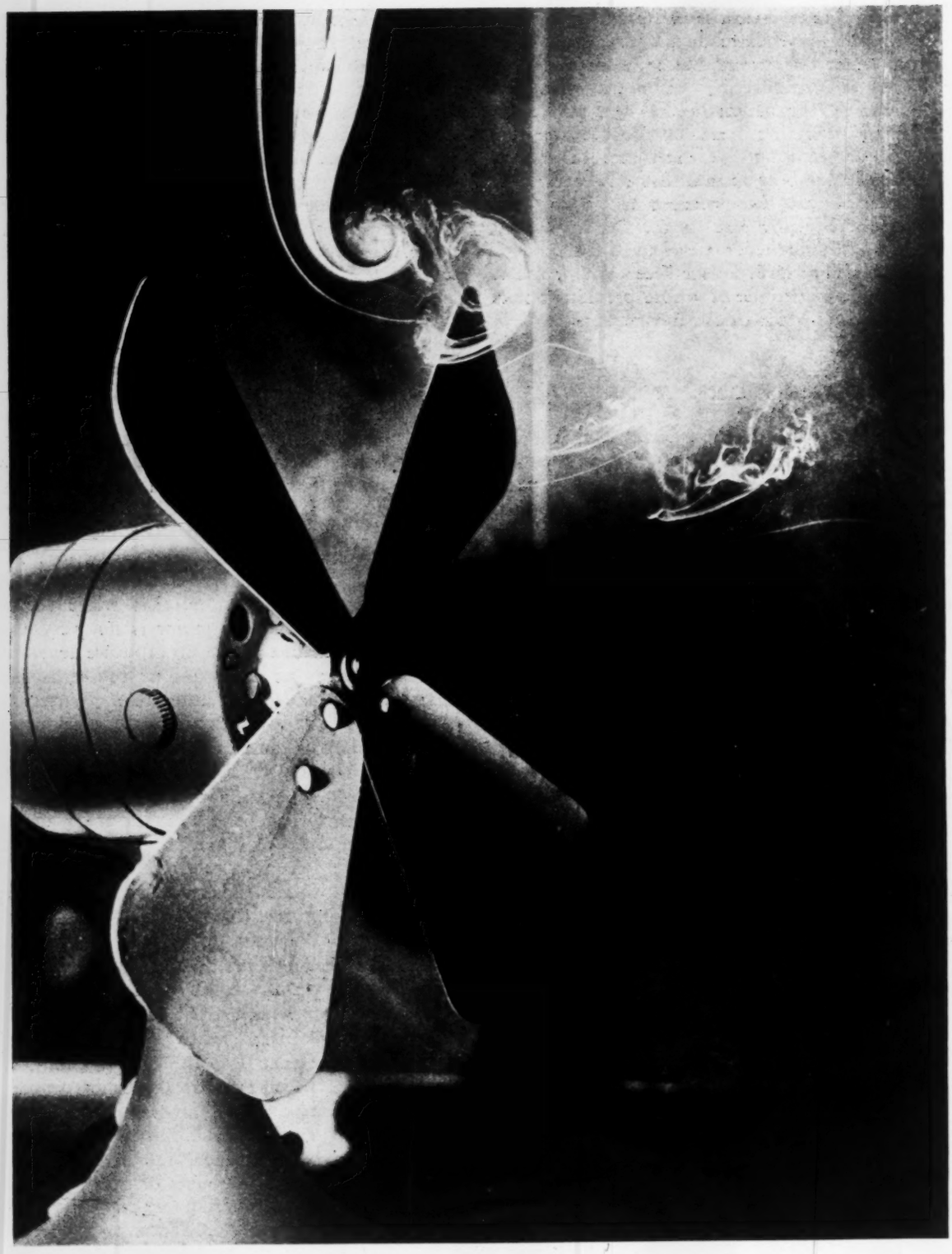
In any event only very clean coals can be used for operating Diesel engines. This brings up another point, i.e., that the Diesel engine has been primarily developed in Germany, where coal is plentiful and oil is scarce and has to be imported from abroad. Even under these conditions, however, the coal-dust engine is not expected to make any very spectacular progress even in its own native country, which would indicate that when to the original cost of coal is added the cost of cleaning and pulverizing, there is no very great margin with which to compensate for the other disadvantages of the new engine.

However, our present methods of cleaning coal are both crude and expensive, with the result that they are applicable only to coals which are naturally comparatively clean. There is a possibility that far better methods of cleaning may provide coal dust of high purity from the ordinary bituminous or lignite deposits. It is also possible that as a result of such a development as that know as the Bergius hydrogenation process, residues in the form of a fuel suitable for combustion in the Diesel motor may be obtained. This would create a situation entirely different from the one existing today and might open great possibilities for the use of Diesel coal engines of the stationary type.

It would appear, therefore, that while the present outlook for the coal-dust motor is not very rosy, the situation may change as a result of future developments. For marine purposes the coal-dust engine as it stands today seems to be entirely unsuitable. Whereas Diesel oil can be obtained today in practically every port of the seven seas the coal-dust engine seems to require a fuel which is not universally obtainable. Except for vessels operating on regular runs the coal-dust Diesel motor does not bear enough promise under the present conditions for use on shipboard.

One more field needs to be carefully considered in this connection and this is the central station. It has been known for a long time that the ideal location for a central station is at the mouth of a mine. Where energy can be conveyed cheaply and efficiently in the form of electric current, it seems foolish to carry the coal to the power plant to be burned there. The chief practical reason why central stations have not been established at the mouth of the mine or in the heart of coal-producing regions is that the present steam-turbine power plant requires, in addition to fuel, large amounts of water for use in condensers and this is not usually available at the mouth of the mine. The coal-dust Diesel engine, however, needs only small amounts of water and could be operated in a satisfactory manner practically anywhere. Incidentally this would simplify the peak-load problem. Even in what might be called large units the output would probably not exceed 20,000 kw. Every Diesel therefore could be operated at full load which is not always possible today with the huge steam units. Under these conditions the plant would show a large degree of flexibility as well as efficiency.

A further report on developments in the coal-dust Diesel will be found in an abstract on page 250.



*"The Instant Made Eternity"*

*(By means of a high-speed camera this moving fan and a vortex of smoke at the blade tip have been photographed.* *See page 228.)*

# *The* ENGINEER *as a* CITIZEN

By ALLAN R. CULLIMORE

NEWARK COLLEGE OF ENGINEERING

OUR colleges and universities—many of them conducted largely at the expense of the general public—are each year graduating great numbers of students splendidly equipped with higher education. Would it not seem strange if even one of these students could secure a degree without receiving some practical instruction as to how to discharge his duties and responsibilities as a citizen? Such, however, is not the exception—unfortunately, it is almost the general rule."

This statement from the opening paragraphs of a pamphlet entitled "The Engineer's Duty as a Citizen," by Dr. Roy V. Wright, past-president of the A.S.M.E., and used by him in leading a series of discussions at the Newark College of Engineering, is certainly a direct challenge to educators everywhere; and directed as it is primarily toward engineering education, it should merit careful consideration on the part of engineers.

It was interesting enough to suggest an attempt to appraise quantitatively the engineer's contribution to his community, his state, and his nation, that is, to the general social fabric outside of the profession.

It is noteworthy that on the basis of a somewhat hurried and casual survey, approximately 31,000 names are listed in "Who's Who in America" and that approximately 19,000 men are listed in "Who's Who in Engineering." Of these 19,000 the names of 1600 engineers are listed in "Who's Who in America."

In looking over these engineers to determine the men who have made outstanding contributions outside the field of engineering, that is, in the field of general public and governmental service, using the term in the broadest sense, we find about 260 engineers who have made some unique and outstanding contribution outside their chosen field.

This does not, of course, indicate that engineers have not made a considerable contribution to the government and to society through the medium of their profession, but it does indicate, it would seem, that such contributions have been narrow and that only in comparatively few cases has the engineer evidenced the desire to step outside his profession into a broader type of service and a broader sphere of helpfulness.

Dr. Roy V. Wright's work as president of The American Society of Mechanical Engineers was characterized by more than usual interest in the problems of the younger members of the Society—student members from whom the Society recruits a very considerable part of its junior members. He visited most of the engineering colleges of the country, addressed during the time of his presidency a large proportion of the student chapters, and as a result, felt so strongly the need to stress the duty of the engineer as a citizen that he consented to undertake personally the responsibility of a discussion group with the upper classmen in the Newark College of Engineering. The work was first instituted in September, 1933, and continued with what would seem to be success and a thoroughly sustained interest through that year and this.

Something of the content of the course and something of its machinery should be of general interest to the profession. In the main, the topics discussed fall under three broad heads:

(1) What responsibilities has the engineer as a citizen?

(2) How can the engineer as an individual discharge his civic responsibility?

(3) How can the engineers as a group discharge their civic responsibilities—local, state, and national?

These three divisions furnish the background for Dr. Wright's first pamphlet which was printed in September, 1933, and which was used as the basis of the discussion course. Dr. Wright sent out about 900 of these pamphlets to engineering educators, engineers, and men in public life and received in reply a considerable number of comments and criticisms. These prove the great necessity for this type of endeavor.

There seems to be a unanimity of opinion that somewhere in the life of the young engineer his attention should be directed quite definitely to duties lying somewhat outside the technique of his own profession. Some of the letters, coming from men high in the profession and of broad viewpoint, deserve greater publicity than they can receive in this article, but it is sufficient to indicate that the returns and the comments and the criticisms set at rest any fears that Dr. Wright may have had concerning the soundness of his judgment in suggesting such a course.

On the basis of the comments and criticisms and on the basis of the experience which was gained in the first year's trial, the pamphlet was revised and expanded for the work of the year 1934–1935.

The material in sections 1 to 6 of the revised pamphlet is designed to furnish a proper background, indicating to the young engineer some of the conditions which he faces and something of their genesis and development.

It would seem worth while in connection with this background material to quote at least one of the opening paragraphs of Dr. Wright's argument:

> Owen D. Young, in addressing a graduating class at the St. Lawrence University, made this significant statement: "I commend to you an examination of what your obligations are in this modern world and a continuing study of how you intend to perform them. Democracies will fail unless you do. The political liberty of the individual will be diminished from necessity unless you do. Dictators will arise to perform your responsibilities, and having performed them, will take their full toll from your liberty. Our colleges are in default in this great field of research and instruction. No diploma should be granted until men and women know something more about the area of their obligations in life and something more about their duty in their performance."

Some very interesting statements under the head of "What the Engineer Has Done for Humanity" stand out as follows:

> Engineers have conferred great material benefits upon humanity. They are largely responsible for this industrial age and all that it means to us. The mass production era, in particular, has brought with it many complications—economic, social, and political. Moreover, engineering projects on a large scale are more and more entering into our governmental activities. The engineer, therefore, even more than the average college graduate, should have a strong sense of his responsibility as a citizen and should understand clearly and concisely how to make his influence felt in public affairs.
>
> It is the rare exception to find an engineering college that places special emphasis upon this, or which attempts to coach its students how effectively and definitely to discharge their civic responsibilities.

A statement by L. P. Alford published in MECHANICAL ENGINEERING in 1930 follows:

> Modern industry, brought in by the machine age, has lessened human

toil, has shortened working hours, has been a factor in extending the span of human life, has brought comfort, leisure, educational and recreational advantages, has increased individual liberty, and has tended to increase happiness. The burden of work has been shifted from human muscles to machinery. The working day has shrunk from fourteen or sixteen hours down to eight or nine. The expectation of human life in the last half of the period we are considering has increased from 48 years to 57 years. Both men and goods now have a mobility undreamed of when The American Society of Mechanical Engineers was founded (1880). And the comforts now found in the average American home are evidence of the possibilities of greater happiness.

Perhaps the two most significant statements are those by Dr. William E. Wickenden, president of the Case School of Applied Science and by Rear-Admiral George Wallace Melville.

Dr. Wickenden said:

Like the young man of the Bible who had kept the law from infancy, but who aspired to an even higher moral perfection, some of us may ask, "What lack I yet?" The answer, as I sense it, would be a more human understanding of the immediate results of our work on men as persons.

Speaking on the engineer's duty as a citizen, the Admiral made this statement:

What I am pleading for is a habit of mind that will cause engineers to take an active part in all public questions, great or small, where their knowledge will enable them to contribute to the common good..... And not until the engineer of all grades has done his part toward the promotion of the highest efficiency of the government, can he truly say that he is, in the fullest sense of the term, a good citizen of the Republic.

Some of the questions which accompany the text of the pamphlet are extremely interesting and perhaps are as suggestive of the course and discussion as any of the material contained in the pamphlet could be. Here are a few:

Have you any idea of the total capital outlay required for your education?

What total financial responsibility do you have to the general taxpayer?

In what way does the state hope to be repaid?

Has increased wealth and great leisure resulted in more contentment and happiness?

Has man advanced ethically, aesthetically, and morally to keep pace with the material advance?

Is the successful functioning of our republican form of government dependent upon a high and active degree of understanding and participation on the part of the average citizen?

What contribution has been made by engineers to the higher and more intangible things in life?

Who of the great engineers has contributed directly to a broader and fuller social status, artistic appreciation, and a better political functioning?

Section 7, the really vital part of the pamphlet, concerns itself specifically with the practical ways in which an engineer can discharge his civic duties; and section 8 touches the very important and fundamental question of engineering ethics.

Of special interest are some thumbnail sketches of certain engineers who have made contributions somewhat outside their profession. Among them are David Cushman Coyle, George W. Farny, Ralph E. Flanders, president of The American Society of Mechanical Engineers, Walter Kidde, Conrad Lauer, and W. H. Winterrowd.

A considerable amount of space is given to the consideration of the activities of the Engineers' Council for Professional Development and the possibilities which this holds for the broadening of the profession.

The method of instruction and the content of the course is somewhat unique and has proved not only interesting but effective and economical. This particular discussion is an integral part of a course for upper classmen intended, at least, to point out to them some of the essential problems, difficulties, and duties which face them as human beings.

The course is closely related to their professional work and it is believed that it is fundamental in the life of every young man. While no attempt is made to study exhaustively the problems of economics, morals, and ethics in this course, its function is to point out and to focus attention upon certain broad human values and to offer the student an opportunity to question and to some extent discuss.

Dr. Wright's work on citizenship is supplemented by a series of discussions by the president of the Newark College of Engineering, on some of the individual emotional, moral, and ethical phases of life.

A series of discussions are held with Bruce B. Robinson, M.D., psychiatrist of the Board of Education, on physical and mental hygiene. One discussion period under the direction of Mrs. Joseph W. Barker is devoted to the personal and social side of an engineer's training.[1]

Each discussion leader outlines his argument or thesis. It is printed and distributed to the students some considerable time before the formal discussion takes place. The material in these pamphlets is discussed preliminary to the formal discussion with the sponsor, and on the basis of these informal talks the students submit the questions in writing which enables the leader of the discussion properly to direct it and stress those points which seem to be fundamental.

The students come, then, to the discussion period with a knowledge of the argument and the background and have already cleared up many of the more superficial and obvious questions considered in the pamphlet. Specifically, it is the objective to have the students come to Dr. Wright's discussion with the decks pretty well cleared, in a position to profit by the material which he is able to contribute. The material given in the pamphlet is never presented to the students by Dr. Wright. The entire time and class is given over to the answering of questions and the asking and answering of questions collateral to the more formal written ones. In fact, the written questions are used very largely as a means of appraisal and as a direction, and no attempt is made to answer all written questions.

One of the most significant things in connection with this work and suggested by it was the appointment of a committee, by Dean A. A. Potter, when he was president of the A.S.M.E. to formulate a Manual on Citizenship for the younger members of the Society. This committee, of which the author is the chairman, consists of Dr. Lillian M. Gilbreth, consulting engineer, Joseph W. Roe, professor of industrial engineering, New York University, William H. Winterrowd, vice-president of Franklin Railway Supply Company, Dr. Roy V. Wright, and is headed by President Cullimore of the Newark College of Engineering. It was felt that some pamphlet like Dr. Wright's deserved rather broader distribution to the members of the Society. This committee decided to use Dr. Wright's revised pamphlet as a basis for their proposed manual, and they have mailed to all the students and junior members of the Society copies of the pamphlet with a letter asking for their direct and frank criticism.

The committee believes that such a pamphlet should meet the needs of the younger men, and the criticism of the student and junior members is extremely desirable in formulating any manual or any policy having as its objective the broadening of the human contacts of the mechanical engineer.

It is rather interesting that work of this character should be instituted first in The American Society of Mechanical Engineers; that this Society should see and appreciate first the fundamental necessity of educating its youthful members in some of the broader considerations of life.

[1] Mrs. Barker's pamphlet on this subject, written especially for this course is entitled "The Personal and Social Side of an Engineer's Training," and is published by John Wiley and Son, New York, N. Y.

# CAVITATION RESEARCH

## *A Progress Report on Work at the Massachusetts Institute of Technology*

By J. C. HUNSAKER

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

A FUNDAMENTAL study of hydraulic cavitation, sponsored by the Safe Harbor Water Power Corporation, has been in progress in the hydraulic laboratory of the Massachusetts Institute of Technology during the last two years. The work was initiated by Professor Spannhake, of Karlsruhe, while a visiting professor, and continued by H. Peters and E. W. Spannhake with the cooperation of various specialists from the faculty. This organization of the research made it possible to apply the techniques of acoustic, automotive, and aerodynamic experts. In particular, the high-speed motion photography of Prof. H. E. Edgerton, the sound recorder of Prof. R. D. Fay, and the automotive indicators of Prof. C. F. Taylor made it possible to reveal the periodic nature of cavitation, to study the birth, growth, and collapse of cavitation even though one cycle takes place within a fraction of a second, and to correlate the frequency of the emitted sound and shock with that of the photographic record.

As it is believed that these results are new and tend to establish the essentially mechanical nature of cavitation, it was thought desirable to obtain full discussion from experts in fluid mechanics, in the interest of our future program of research. To this end, Prof. R. H. Smith made a progress report before the Berkeley meeting of the A.S.M.E. in June, 1934, the writer made a similar report before the Institution of Naval Architects in London and before the International Congress for Applied Mechanics at Cambridge University in July, 1934, and E. W. Spannhake made a report before the general meeting of German Physicists and Mathematicians at Bad Pyrmont in September, 1934. These progress reports included the slow projection of the Edgerton high-speed motion pictures which, unfortunately, do not lend themselves well to publication. We do, however, include here a reproduction of enough frames of the picture to show a complete cycle of the cavitation collapse.

The objective of the research was to determine the mechanism by which hydraulic cavitation damages boundary walls. Our evidence substantiates the opinion of other investigators (1, 2)[1] that this mechanism is mechanical in nature. We cannot describe the exact mechanism by which wall damage results, but there must be some connection with the fluctuation of pressure resulting from the collapse of water vapor which periodically becomes unstable in such vapor phase. We measured the shocks and have photographed the periodical formation and collapse of vapor for a few simple cases.

Furthermore, we have found that the severity of damage due to cavitation depends on the shape of the boundary walls and on the air content of the water used. Corroboration of the mechanical nature of the action has been obtained by causing damage to plate glass and to a lead plate without loss of weight. A lead tube fixed in a hole in the pipe near the region of vapor collapse burst near the outer and sealed end, regardless of the length of the tube, as if by water hammer. The damage to glass or other metal boundary material took place only opposite the region of vapor collapse. The appearance of such materials, after short exposure is such as would be caused by inaccurate shots at a target. At first, a few scattered hits are recorded but, eventually, a closely defined area is thoroughly peppered.

The apparatus used, shown in Fig. 1, permits control of velocity, pressure, temperature, and air content. The test section is a two-dimensional venturi nozzle two feet long, in which various shapes or profiles could be inserted as two sides, with flat plates of glass or metal forming the other two sides.

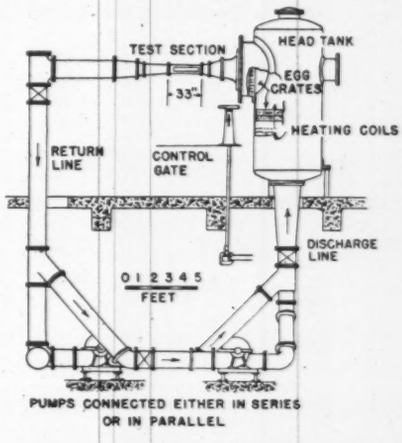



FIG. 1 GENERAL ARRANGEMENT OF APPARATUS

Fig. 2 shows some of the profiles tested. Severity of cavitation damage was greatest for a divergence of the venturi, or exit flare of 10.5 deg on each side. For greater flare, marked cavitation took place, but with little or no damage. It is a fair inference, confirmed by visual observation, that when the stream surrounds the region of vapor, or cavitation, the collapse is harmless.

Fig. 3 shows the appearance of cavitation for a typical profile viewed through the glass sides of the nozzle. The length of the cavitation volume is characteristic, and determines the loudness of noise, the damage observed, and the additional loss of head due to cavitation. The visual length of vapor is shown to be related to the longitudinal pressure distribution along the nozzle. The vapor is seen to collapse where the pressure rises sharply and to extend no further. Just here is the region where the side walls are damaged. Relatively little damage occurs on the flared sides of the nozzle. For use in dimensional analysis of other relations, the characteristic length was taken from pressure-distribution curves by finding the point of maximum pressure rise. The distance from the throat to this point proved to be about the same as the visual length in the figure.

For profiles of ordinary form, the air content of the water seems to have no important effect on the cavitation, but Fig. 4

[1] Numbers in parentheses refer to the bibliography at the end of the paper.

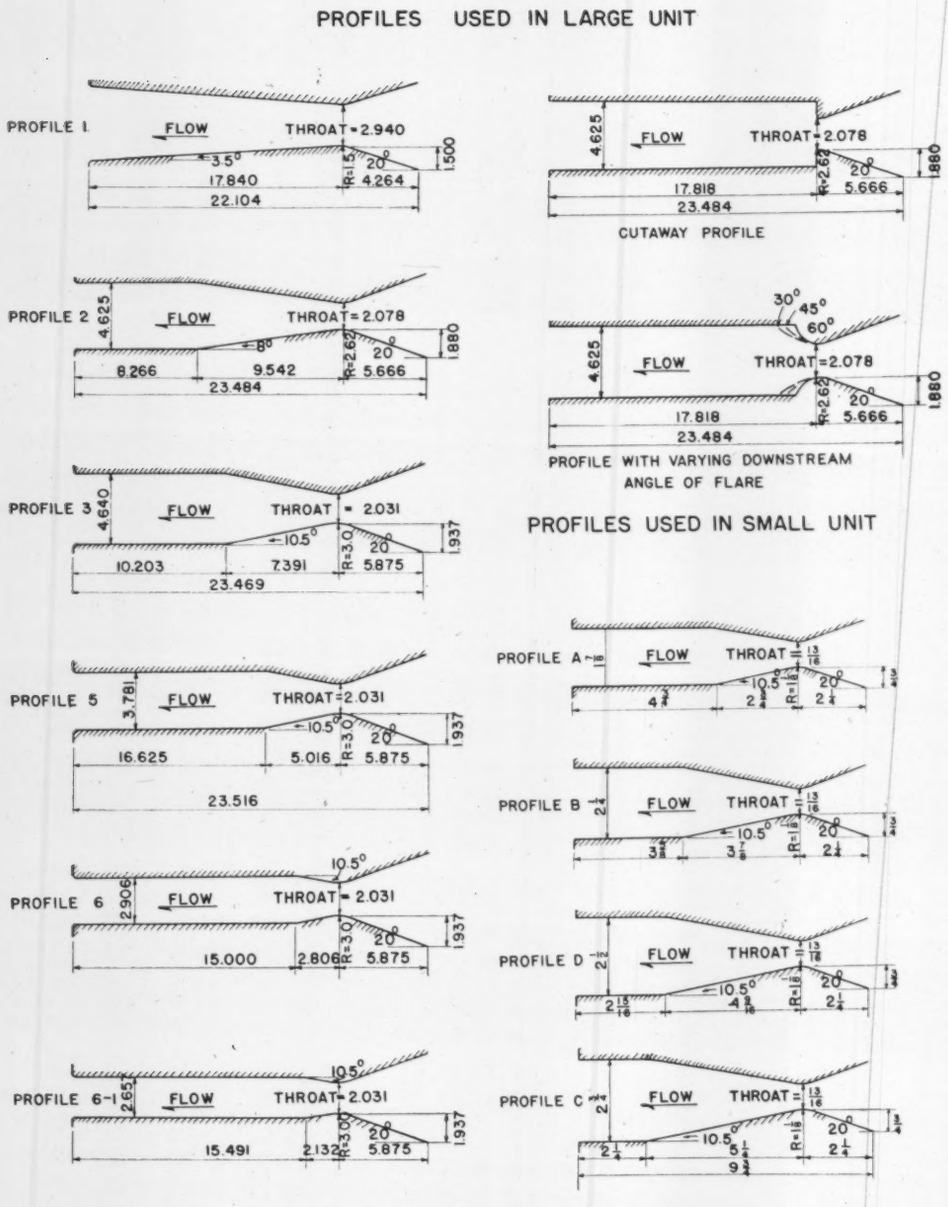



FIG. 2 PROFILES TESTED

shows that as the pressure at the throat falls below 150 mm there must be a change in velocity pattern at the throat, since the "square law" relating velocities and pressures no longer holds true. We suggest that air coming out of solution is the cause of this upset.

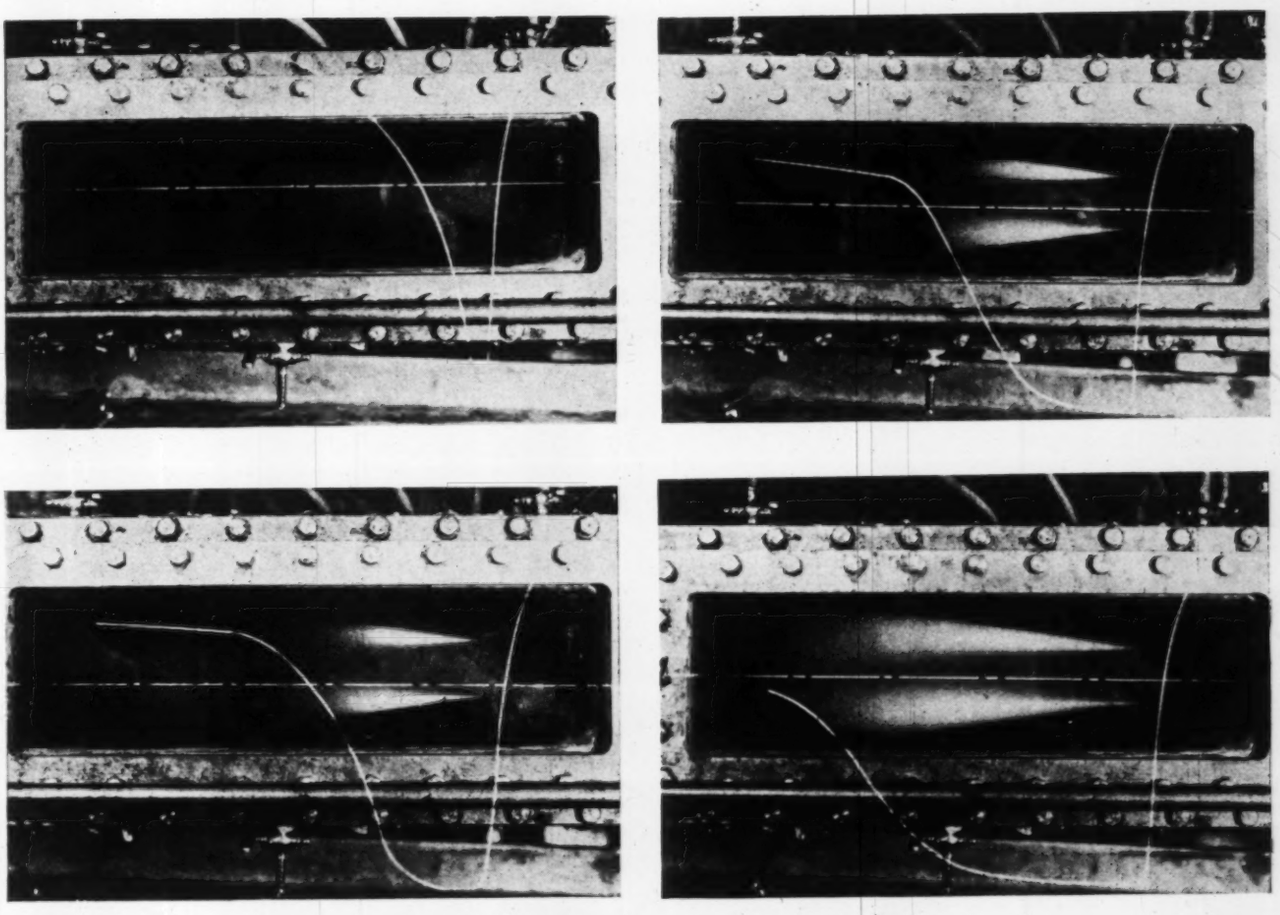
To give air in solution more time to come out, profile 4 with a long throat was made. Fig. 5 shows that cavitation begins at pressures much higher than the true vapor pressure for water at the temperature of the test. The water was seen to become milky as air came out of solution, and obviously the density of the stream was reduced. Evidently the flow pattern is changed, and cavitation starts while the throat pressure is still well above 20 mm Hg (at 24 C). With higher air content, cavitation is more easily produced. This effect may have more important implications in the design and testing of hydraulic machinery.

A further effect of air content lies in its apparent cushioning of the shock due to the collapse of cavitation vapor. Fig. 6 shows how lead tubes projecting from the side of the nozzle were elongated progressively with length of exposure. Such a sealed tube integrates the work done by successive shocks. With 1 per cent air content the tubes stretch five times as far as with 3.8 per cent air, in the same time under the same hydraulic conditions.

The foregoing summarizes the evidence of the more practical aspects of cavitation, its production, and its effects. We are convinced that its effects are purely mechanical, although chemical change in material surfaces (brass, for example) may be accelerated by high surface stress.

To go more deeply into the nature of the mechanism, we applied the technique of the acoustic engineer to measure and analyze the sound, and that of the automotive engineer to measure the pressures.

Fig. 7 shows typical oscillograph records of the amplified voltage picked up by an ordinary earphone set in liquid in communication with the outside of the nozzle, and by a micro-



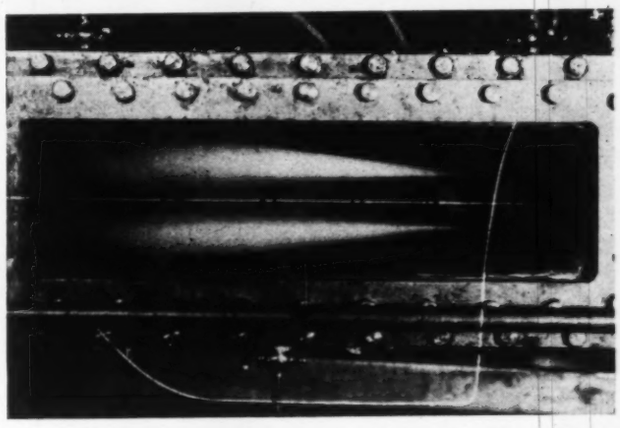


FIG. 3 RELATION BETWEEN LENGTH OF CAVITATION AND DISTRIBUTION OF PRESSURE ALONG AXIS OF PROFILE WITH CONSTANT DISCHARGE

phone in the air near the nozzle. We also used the Draper moving-coil engine indicator (3) and the G. M. carbon-pile engine indicator (4) in communication with the water in the nozzle. These records all reveal the same periodicity of high pressure.

That this period is not inherent in the geometry of the apparatus is inferred from the tests, which show the frequency to vary with throat velocity for a given profile and to vary with the length of cavitation. Furthermore, the frequency is different for different profiles.

In addition, profile *A*, similar to No. 3, was constructed half-size and used near the free end of a pipe extending from a standpipe. See Fig. 8. The frequency for this profile in the open system was very much higher than that of the larger profile in the closed system, yet the non-dimensional number, relating frequency, velocity, and length of cavitation, remained substantially constant.

It seems clear, from Table 1 in which are given the variables, that frequency must be an attribute of the characteristic length of the cavitation and the velocity, and, presumably, of the shape of the nozzle, but is independent of the form of the general hydraulic system.

Fig. 9 shows 25 frames of a moving picture taken with transmitted light at 3000 exposures per second by H. E. Edgerton (5). This magnification of the time-scale allows us to see that the presence of vapor in the cavitation length on one size of the nozzle's flare is periodic.

The frames 1 and 2 show a cavity extending from the throat downstream; the formation of vapor ceases at the throat (frames 3 and 4), and the cavity moves downstream and condenses, while in the meantime, a new cavity forms at the throat (frame 5), and extends progressively downstream as can be seen in the succeeding frames.

The condensation of the remainder of the previous cavity, or the final collapse, occupies but a few frames or approximately $^1/_{600}$ to $^1/_{1000}$ sec. Furthermore, the collapse is seen to take place opposite the area of damage of the side walls. In addition we will remember, this damage is also near the point where the rate of rise of average pressure is a maximum.

TABLE 1

| Profile | $L$ Length, in. | $V_{th}$ Velocity ft per sec | $f$ Frequency | $fL/V_{th}$ Dimensionless frequency |
|---|---|---|---|---|
| 3 | 15.2 | 84.6 | 27.7 | 0.42 |
| 3 | 15.2 | 84.6 | 28.2 | 0.42 |
| 3 | 15.2 | 14.6 | 28.4 | 0.43 |
| 3 | 15.2 | 49.16 | 16.1 | 0.42 |
| 3 | 15.2 | 49.16 | 16.6 | 0.43 |
| 3 part. plate | 15.2 | 86.8 | 29.5 | 0.43 |
| 3 | 7.8 | 86.1 | 41.2 | 0.31 |
| 3 | 7.8 | 49.95 | 26.9 | 0.35 |
| 6 | 4.37 | 64.41 | 60 | 0.34 |
| 6 | 4.37 | 83.34 | 75 | 0.33 |
| 6 | 4.37 | 91.54 | 82.5 | 0.33 |
| *B* | 3.752 | 82.2 | 103.7 | 0.39 |
| *A* | 3.53 | 72.64 | 110 | 0.44 |
| *A* | 3.53 | 92.5 | 139.9 | 0.44 |
| *A* | 3.53 | 113.4 | 172.5 | 0.44 |

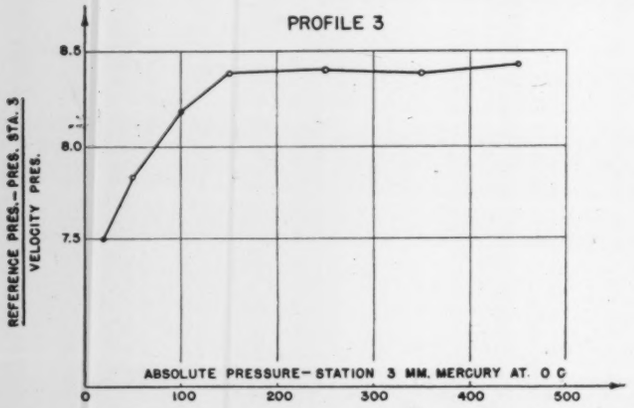



FIG. 4 PLOT SHOWING BREAKDOWN OF SIMILITUDE AS CAVITATION IS APPROACHED, PROFILE 3

The frequency of this collapse is the same as that measured by microphone and by pressure indicator, and this collapse, therefore, seems to be the cause of sound and pressure waves. It is interesting to note that at the instant of collapse, or two frames later, vapor ceases to form at the throat. This is possibly due to pressure waves generated by vapor collapse raising the throat pressure above the vapor pressure. A plunger of clear water then seems to pass for a short period until vapor forms again at the throat.

The plunger gains in mass as it fills the exit flare, and, by analysis of the photographs, its mean speed was found to be less than half the velocity of the throat. As vapor begins to condense, water has to be accelerated to take its place. There should be no appreciable shock as long as vapor remains and prevents a sudden acceleration of the water. It is probable that the collapse of the last of the vapor (possibly frames 19 to 24) takes place in contact with the parallel side walls, while the plunger joins with the more slowly moving downstream body of water, starting in the plane of symmetry of the nozzle.

This collapse can be of immense

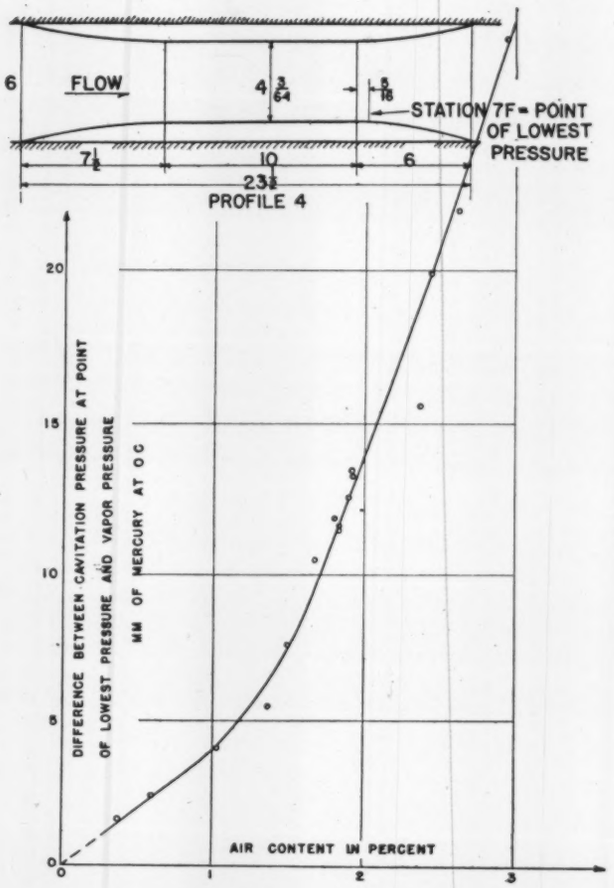



FIG. 5 RELATION OF AIR CONTENT AND PARTIAL PRESSURE OF AIR IN CAVITATION VOLUME

(Pressures measured at station 7F with constant cavitation conditions. Temperature range, 24.1 to 27.5 C.)

local intensity and might be the fundamental mechanism causing wall damage. There is possibly a time lag in the response

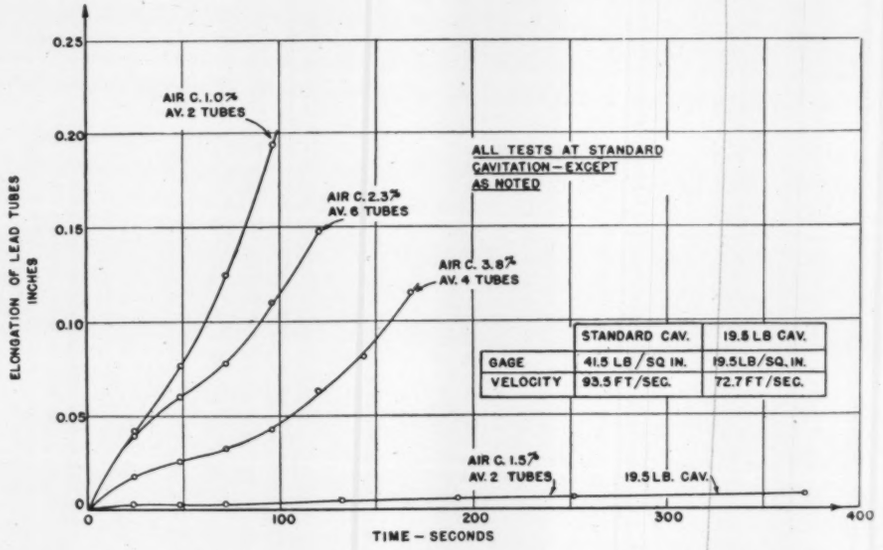
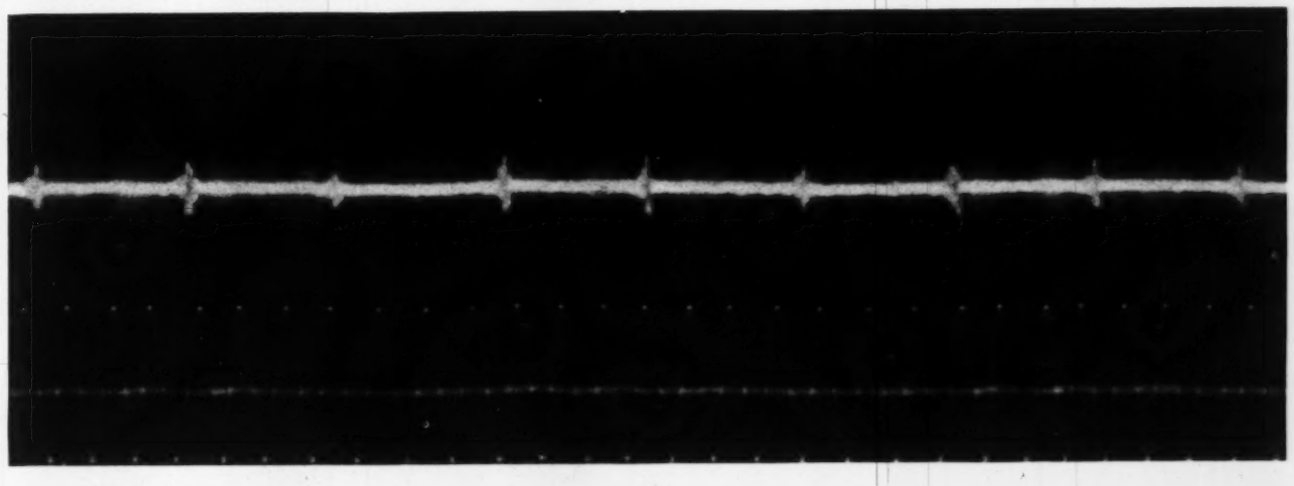
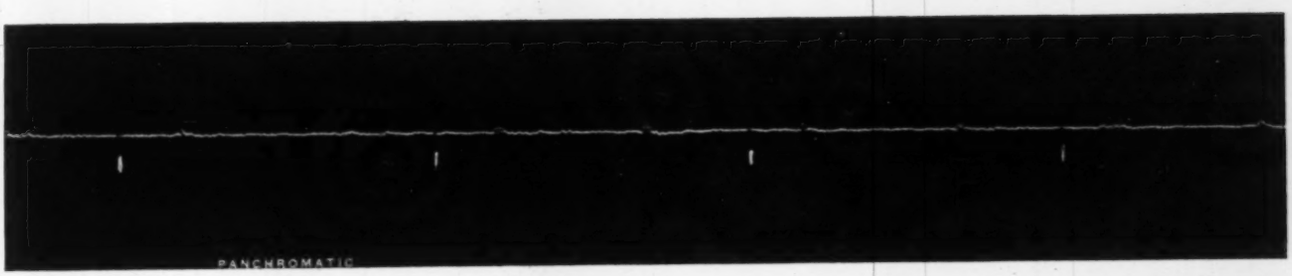



FIG. 6 RELATION OF AIR CONTENT AND CAVITATION SEVERITY

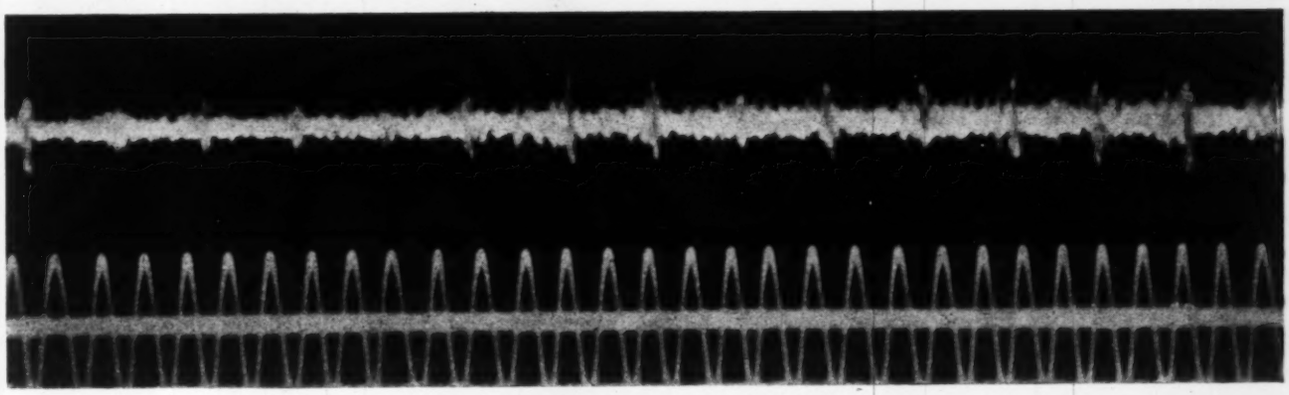
(Using lead tubes of 3/8 and 3/16 in. diameter.)



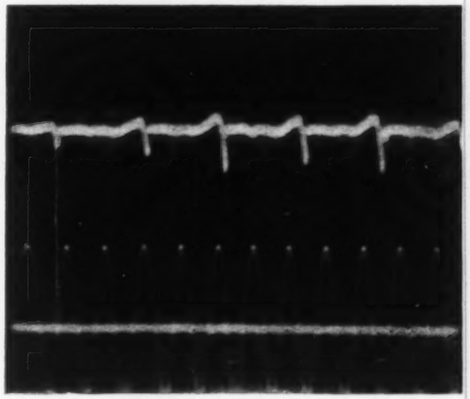
(*a*)




(*b*)



(*c*)



(*d*)

(*a*) Earphone Oscillogram

(*b*) Microphone Oscillogram

(*c*) Moving-Coil Indicator Diagram

(*d*) Pressure-Measuring Device Oscillogram

FIG. 7 TYPICAL OSCILLOGRAMS FROM VARIOUS DEVICES FOR MEASUREMENT OF FREQUENCY

of vapor to virtual supercooling, and condensation is delayed enough to permit both periodic accumulation and discharge of energy.

The areas of such eventual collapse should, under this hypothesis, be small and should be scattered about some definite spot on the wall. Our experiments show such scattering, and indicate local damage over extremely small areas (less than 1 mm). Further confidence in this conception is given by our

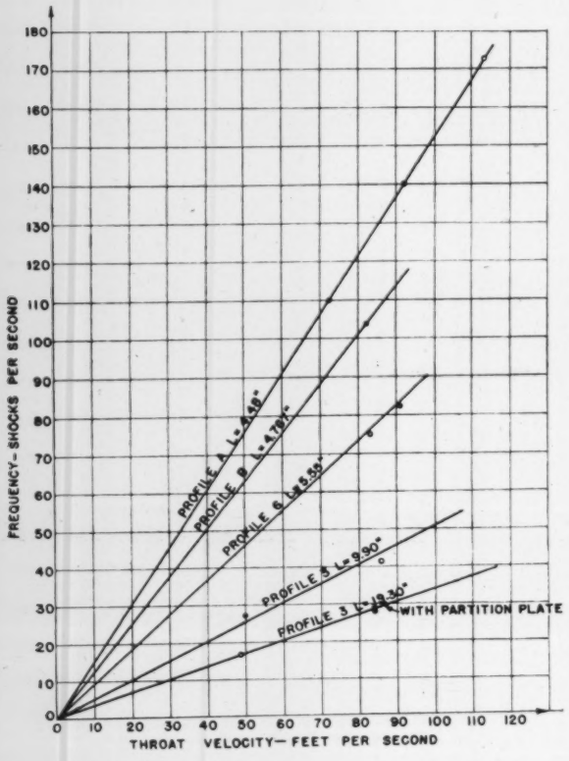



FIG. 8 RELATION OF FREQUENCY AND VELOCITY FOR VARIOUS PROFILES

complete lack of success in measuring the severity of cavitation damage by means of a tiny diaphragm inserted in the wall. The diaphragm was burst sometimes instantly and sometimes after appreciable time of exposure. Perhaps, to use a ballistic analogy, a hit has to be waited for. A scattering of hits both in space and time is consistent with the view here presented. A great deal of further work must be done before the problem can be explained quantitatively, and further information is needed to define the vapor structure inside the cavitation volume.

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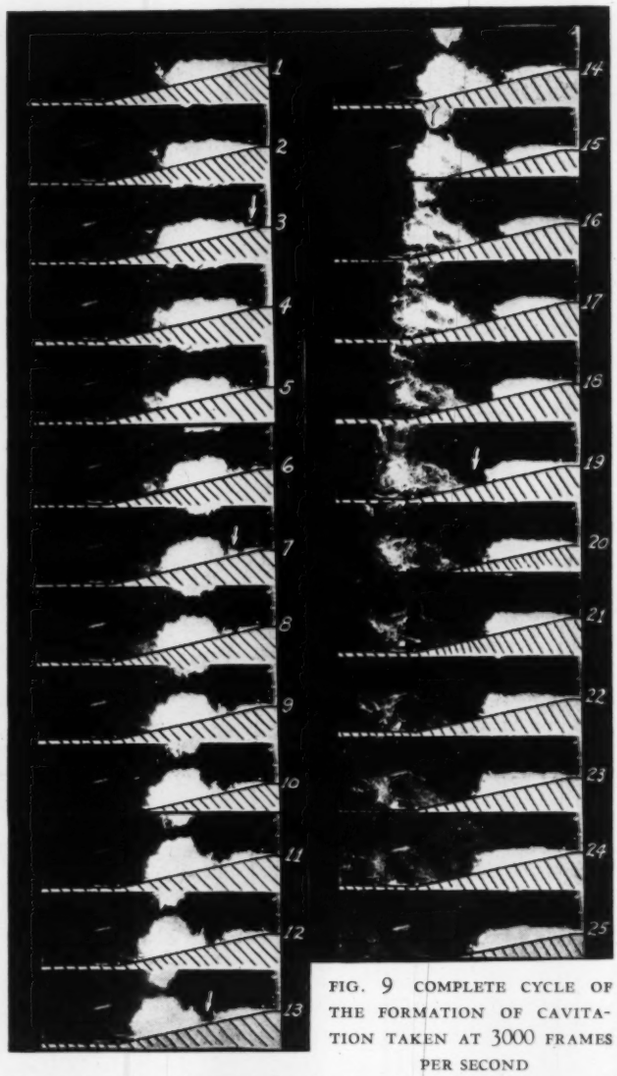

FIG. 9 COMPLETE CYCLE OF THE FORMATION OF CAVITATION TAKEN AT 3000 FRAMES PER SECOND

(Movement of the water plunger (indicated by an arrow) from its creation at the throat until it rejoins the main body of water.)

## The Engineer and the Metallurgist

THAT engineering progress depends largely on complete collaboration between the engineer and the metallurgist, and that great possibilities would be opened up as a result of further systematic research in metallurgy, were among the points emphasized by Mr. A. J. Grant, in the course of his presidential address, delivered before the Sheffield Society of Engineers and Metallurgists, on January 21. The engineering conception, based on increasing knowledge of physical laws, could, at times, he stated, see the mechanical progress possible—provided a suitable metal, having the necessary mechanical and physical properties, was available, and the more completely the engineer and the physicist disclosed their dependence upon certain directions of metallurgical development, the sooner would the needs be met. While complete collaboration could easily be accepted as an abstract idea, it was unfortunately still far from being acknowledged in practice. The electrical engineer who designed rotor forgings having a shape suitable for his requirements, but the very worst possible from the metallurgist's and steelmaker's point of view, was a case in point. —*Engineering*, Feb. 1, 1935, p. 125.

# ENGINEERING METHODS *in* MEDICAL RESEARCH

By CHAS. MURRAY GRATZ and S. N. BLACKBERG

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ENGINEERING determinations have heretofore been applied only superficially to medical research, despite the fact that the knowledge of these factors is of importance to the engineer in the development of many mechanical devices. Much stress and strain to which the human body is subjected is transmitted or absorbed by fibrous connective tissues. In fact, these tissues are strained even when the body is at rest. This paper reports a technique that has been evolved which permits accurate measurement of the tensile strength, elasticity, and elastic limit of the fibrous tissues of the body. These determinations are of definite value in surgery and may contribute to the solution of problems in the study of the mechanics of the human body.

The strength of elastic diaphragms, such as fibrous tissues, would be evaluated by the engineer in terms of tensile stress and shearing stress. Fibrous tissues do not carry compressive, bending, or torsional loads. Tensile stress results from the application of a load in the direction of the fibers, and the fibers are ruptured when the load exceeds the tensile strength of the tissues. The maximum strength of samples of such tissues is shown in Table 1.

When the load is not parallel to the fibers, a combination of shearing stress and tensile stress results. Shear phenomena have apparently been given but little consideration by surgeons.

Living fibrous tissues are now surgically transplanted from one part of the body to another for the repair of anatomical defects. These living sutures must necessarily withstand considerable stress and strain in the performance of their new functions. Knowledge of their tensile properties is of value in determining the proper size and type of suture to use. This, together with knowledge of shear phenomena, has led to better results with this type of operation. Many surgical failures of the past may be avoided in the future by application of this new knowledge. Common sprain, for example, which we have all experienced, is often produced by overstressing the tissues in shear.

The engineer's conception of elasticity has been overlooked by the surgeon in favor of the popular conception of "stretchability." The standard measure of elasticity in terms of Young's modulus is presented in this article for the tissues studied. It was difficult with the available equipment to determine accurately the elongation of tissues under stress after the beginning of tear to the point of rupture. The proportional limits were determined from the stress-strain diagrams.

In the study of biological material, the proportional limit determines what may be termed the physiological range of elasticity. This range is shown in the composite graphs in Fig. 1. It is of interest that the physiological range of elasticity extended to a load of at least 500 kg per sq cm in all the species studied. How much stress may be applied in biological structures up to this point and repeated without permanent damage was still undetermined. The application of load beyond the physiological range of elasticity results in separation of the fibers in biological structures. This permanent damage corresponds to the permanent set in inorganic materials. In fibrous tissues rupture occurs, and in bone a fracture results when this range is exceeded.

## DESCRIPTION OF EXPERIMENTAL WORK

The experiments from which the data and results reported in this paper were derived were conducted on fibrous tissues taken from several parts of the bodies of animals, such as sheep, rabbits, dogs, and goats. Tissues from the human body were also investigated, and the results compared with the others. In the present paper results from tests on an adult sheep are presented in detail in Table 1 and Fig. 1. Similar data were obtained from other tests on other experiments.

A Schopper strength tester, commonly used for determining the strength and elongation of paper and cardboard, was employed in obtaining the experimental data. When the tissues were properly placed in the two clamps of this testing machine, the application of load substantially resulted in stress being applied parallel to the direction of the fibers of the test piece. By this method the stresses that would result normally in the tissues when they were functioning in the body between two points were approximated.

Determinations were desired for tensile strength, elasticity, and proportional limit. The technique was therefore designed to reduce or eliminate any other factors which might interfere with the accurate determinations of these three measurements. The preliminary tests were found to be very irregular and, on rechecking the results, the two principal offenders were found to be shear and trauma. The technique was therefore revised to reduce these factors to a minimum. Three lines were drawn with a special dye transversely across each piece, and as long as these lines remained parallel we regarded such tests as being satisfactory. Divergence of these lines indicated slipping of the fibers, probably resulting from shear stress, and the test was discarded. The tests discarded account for the numbers not being consecutive in all cases.

The results of the tests will be of greater value if the minute technique is followed from the time the animals were sacrificed until the test data were made available for study.

The tissues were exposed and any adipose tissue was removed by sharp dissection under moderate tension with a minimum of trauma. The removal of fatty tissue is important not only in testing fibrous tissues but also in transplanting them.

After the tissues were removed from the animal they were placed in gauze moistened at regular intervals with Ringer's solution until the time of testing. Knowing the time at which the animals were sacrificed, the time of the first test, and also the total time of testing, permitted the determinations of the time factor. It may be noted that this factor was found to have little bearing on the tensile properties of the tissues as long as they were kept under suitable conditions.

The large specimens first removed were divided into test pieces. These specimens were placed under tension on a board with the fibers parallel to the grain of the wood. Bard-Parker No. 11 blades were used and the scalpel was held vertically, while the cut was made parallel to the fibers. It was noted that the blades dulled easily, necessitating frequent change. When the blade was even slightly dull, the tissues between the fibers gathered ahead of the blade and resulted in excessive trauma. Four to seven test pieces were prepared at one time.

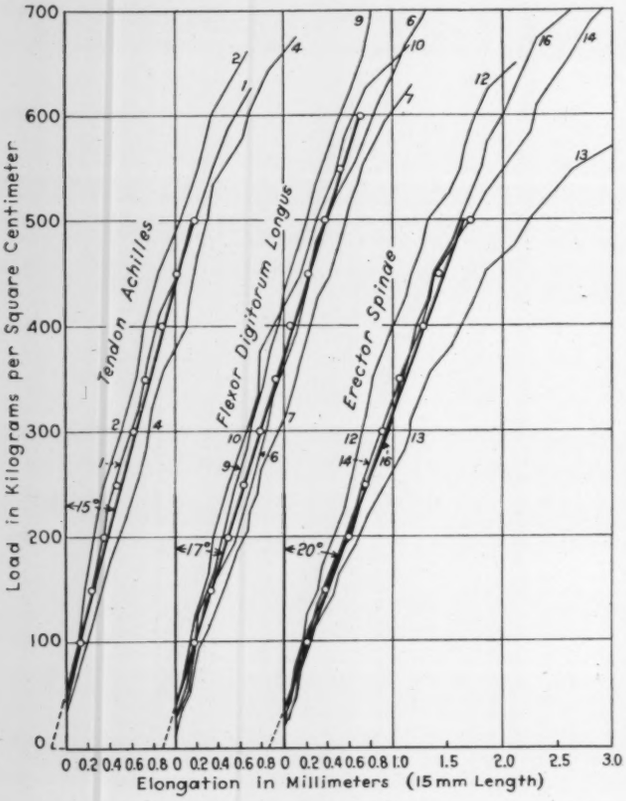


FIG. 1 TENSILE TESTS OF FIBROUS TISSUE OF AN ADULT SHEEP

The following technique was used to determine accurately the cross-sectional area of the specimen. Two glass slides were carefully checked for uniformity and their thickness determined. The test piece was placed between these slides and four paper clips placed over both slides at fixed points. This gave an even tension for all tests. Indicating calipers, Fig. 2, were used to ascertain the total thickness of slides and specimen. When necessary, readings were taken in four to six different locations, and in the event of any variations between readings the results were averaged. By subtracting the thickness of the slides it was possible to determine the thickness of the specimen.

Without removing the specimen from between the slides, two clips were removed, leaving one clip on either end. Direct

TABLE 2 SPECIMEN TEST RECORD—TEST NO. 1

(Animal, sheep, female—18 months; weight, 16 kg; tissue, Achilles tendon; time of death, 3:30 p.m.; time of test, 5:30 p.m.; Date, Nov. 20, 1933; maximum tensile strength, 681 kg per sq cm; length, 15 mm; width, 3.75 mm; thickness, 0.30 mm; area of cross-section, 1.1 sq mm)

| 1 Correction, kg per sq cm for varying size of specimen | 2 Load, kg | 3 Elongation, mm | 4 Correction calculations to plot original readings at increase of 50 kg per sq cm |
|---|---|---|---|
| 45 | 0.5 | 0.0 | 100—0.12 |
| 91 | 1.0 | 0.1 | 150—0.23 |
| 136 | 1.5 | 0.2 | 200—0.32 |
| 180 | 2.0 | 0.3 | 250—0.42 |
| 225 | 2.5 | 0.35 | 300—0.61 |
| 271 | 3.0 | 0.50 | 350—0.70 |
| 318 | 3.5 | 0.65 | 400—0.85 |
| 364 | 4.0 | 0.75 | 450—1.05 |
| 410 | 4.5 | 0.85 | 500—1.20 |
| 455 | 5.0 | 1.05 | ... ... |
| 500 | 5.5 | 1.20 | ... ... |
| 545 | 6.0 | 1.35 | ... ... |
| 590 | 6.5 | 1.50 | ... ... |
| 635 | 7.0 | 1.70 | ... ... |
| 682 | 7.5 | (Tissue broke at 7.5 kg) | |

TABLE 1 TENSILE TESTS OF FIBROUS TISSUES OF ADULT SHEEP

| Test No. | Area of cross-sect., sq mm | Maximum tensile strength: Kg per sq cm | Maximum tensile strength: Lb per sq in. | Elongation in mm for loads in kg per sq cm in 50-kg intervals: 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | Observations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Tendon Achilles* | | | | | | | | | | | | | | | |
| 1 | 1.1 | 681 | 9670 | 0.12 | 0.23 | 0.32 | 0.42 | 0.61 | 0.70 | 0.85 | 1.05 | 1.2 | ... | ... | Tests satisfactory throughout |
| 2 | 0.99 | 690 | 9798 | 0.1 | 0.15 | 0.25 | 0.33 | 0.5 | 0.65 | 0.7 | 0.85 | 1.05 | ... | ... | |
| 4 | 1.4 | 700 | 9940 | 0.18 | 0.33 | 0.51 | 0.65 | 0.78 | 0.85 | 1.1 | 1.2 | 1.3 | ... | ... | |
| Average | ... | 690 | 9798 | 0.13 | 0.24 | 0.36 | 0.47 | 0.63 | 0.73 | 0.88 | 1.03 | 1.18 | ... | ... | Young's modulus for composite graph, 5598 |
| Actual range | ... | 2% | 2% | 0.05 | 0.09 | 0.15 | 0.18 | 0.15 | 0.12 | 0.22 | 0.18 | 0.13 | ... | ... | |
| *Flexor digitorum longus* | | | | | | | | | | | | | | | |
| 6 | 1.8 | 750 | 10650 | 0.2 | 0.35 | 0.6 | 0.7 | 0.82 | 0.95 | 1.12 | 1.95 | 1.4 | 1.6 | 1.8 | Peripheral end of tendon much harder than proximal end. Properties of both approximately the same |
| 7 | 2.7 | 648 | 9201 | 0.28 | 0.47 | 0.62 | 0.8 | 1.02 | 1.15 | 1.28 | 1.48 | 1.55 | 1.68 | 1.9 | |
| 9 | 1.6 | 887 | 12595 | 0.18 | 0.3 | 0.4 | 0.55 | 0.68 | 0.81 | 0.95 | 1.05 | 1.2 | 1.3 | 1.5 | |
| 10 | 1.2 | 666 | 9457 | 0.12 | 0.2 | 0.32 | 0.48 | 0.63 | 0.80 | 0.92 | 1.15 | 1.3 | 1.5 | 1.7 | |
| Average | ... | 737 | 10465 | 0.19 | 0.33 | 0.49 | 0.63 | 0.79 | 0.93 | 1.07 | 1.23 | 1.36 | 1.52 | 1.7 | Young's modulus for composite graph, 4906 |
| Actual range | ... | 20% | 20% | 0.09 | 0.14 | 0.17 | 0.17 | 0.23 | 0.22 | 0.21 | 0.25 | 0.19 | 0.22 | 0.2 | |
| *Erector spinae* | | | | | | | | | | | | | | | |
| 12 | 2.0 | 660 | 9372 | 0.18 | 0.3 | 0.45 | 0.6 | 0.7 | 0.8 | 1.0 | 1.15 | 1.3 | ... | ... | Easily worked and in good condition |
| 13 | 2.05 | 631 | 8960 | 0.25 | 0.48 | 0.70 | 0.9 | 1.12 | 1.3 | 1.6 | 1.82 | 2.25 | ... | ... | |
| 15 | 1.8 | 727 | 10323 | 0.2 | 0.4 | 0.6 | 0.7 | 0.85 | 1.05 | 1.24 | 1.38 | 1.7 | ... | ... | |
| 16 | 2.0 | 725 | 10295 | 0.2 | 0.35 | 0.6 | 0.75 | 0.95 | 1.05 | 1.2 | 1.35 | 1.6 | ... | ... | |
| Average | ... | 686 | 9741 | 0.21 | 0.38 | 0.59 | 0.74 | 0.90 | 1.05 | 1.26 | 1.42 | 1.71 | ... | ... | Young's modulus for composite graph, 4121 |
| Actual range | ... | 8% | 8% | 0.03 | 0.10 | 0.14 | 0.16 | 0.22 | 0.25 | 0.34 | 0.40 | 0.54 | ... | ... | |

Clinical data: Sheep "A;" weight, 16 kg; adult, female; test began 5:30 p.m. and concluded 8:04 p.m. Animal sacrificed to check an experiment in thoracic surgery, 3:30 p.m., Nov. 20, 1933. Animal hospitalized for a long time.

readings were taken against light and the same indicating calipers were used to determine the width of the test piece. In case of any disparity, the readings were averaged. The areas of the cross-section were computed from the dimensions so determined and are recorded in Table 1.

The lengths of the test specimens were standardized by placing the clamps 15 mm apart.

Difficulty was experienced in holding the test pieces in the clamps of the machine. A piece of sandpaper was folded, and the end of the test piece placed between the rough surfaces. The specimen, enclosed in sandpaper, was then placed in the upper clamp and the clamp tightened. The same procedure was followed in inserting the tissues in the lower clamp, and before this was tightened the specimen was checked against uprights to be certain that the fibers would be parallel to the direction of stress. When this was done, the clamps were tightened. Then the three lines of dye were applied, and the test was ready to run.

In conducting the test the load was augmented in increments of 0.5 kg. Elongation was magnified approximately three and one-half times, and greater accuracy was obtained by using a vernier scale and a magnifying glass. After a little practice in the reading, amounts of less than one-twentieth of a millimeter were estimated. The test was carried to rupture.

### TEST RECORDS, GRAPHS, AND TABLES

Readings were recorded while the tests were being run. The results of test No. 1 are recorded in Table 2. The readings

FIG. 2 INDICATING CALIPERS USED FOR MEASURING DIMENSIONS OF TEST SPECIMENS

of the load are in column 2, the elongation in column 3, the correction of varying sizes of specimen to kilograms per square centimeter is given in column 1, while column 4 gives the calculation at increases of 50 kg per sq cm. This method permitted the comparison of the test data in standard form. Test data from several such records have been assembled in Table 1, where the data of Table 2 appear in the first line.

The individual graphs of which those of Fig. 1 are samples

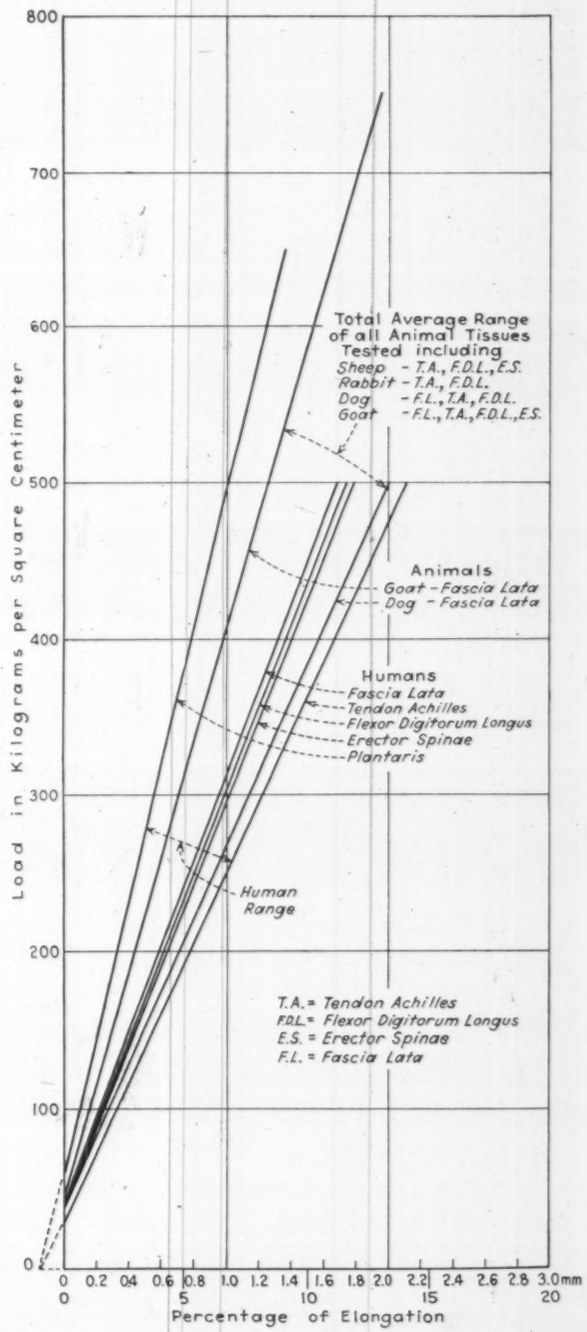


FIG. 3 SUMMARY OF RESULTS OF TENSILE TESTS OF FIBROUS TISSUES
(Graphs are not plotted beyond proportional limit. Data from tissues resulting in curved graphs are not included.)

were drawn from the test records. The individual curves can be related to Table 1 by means of the test numbers. The vertical scale of Fig. 1 represents the load and the horizontal scale the corresponding elongation of a test piece 15 mm long.

The individual graphs of each group in Fig. 1 were averaged to permit the presentation of composite graphs representing

test data from one tissue of one animal. This was done by averaging the readings of the individual graphs where they cross certain load lines, namely, 50 kg per sq cm. The figures from which these average points were plotted will be found in Table 1. The average points so obtained appear on the graphs as circles. By drawing a line through these circles a composite graph was obtained. It will be noted that this composite graph is continued only to a point where it is still approximately a straight line, thus determining the proportional limit. In the terms in which these graphs are presented, Young's modulus may be obtained by multiplying the stress at any point selected on the graph by 1.5 and dividing by the elongation at the same point. It will be noted that the graphs have a correction for true zero to aid in determining the elongation.

Table 1, which is typical of the data obtained in the complete series of tests, contains the clinical data on the animal tested in addition to calculations for plotting the composite graphs. The maximum tensile strength in kg per sq cm and lb per sq in. is also recorded in Table 1.

### FACTORS OF ERROR IN THE TESTING AND TABULATION OF RESULTS

Variations in measuring the thickness and width were multiplied in the determinations of cross-sectional area. This factor of error was lessened by using a magnifying glass to increase the accuracy of reading of these determinations. Indicating calipers and uniform pressure under which the specimens were measured further reduced this factor. The readings of elongation were measured to 0.05 mm and could show a variation of this amount in either direction. The total length of the test specimen being 15 mm, this factor of error was not excessive. The graphs were corrected for the necessary initial tension. The individual graphs show a satisfactory consistency.

### SUMMARY

In addition to the tests reported in Table 1 and Fig. 1, tests were made on other sheep, and on dogs, rabbits, goats, and humans. A summary of representative graphs of all tests is plotted in Fig. 3. Other features of this research have been reported and are to be published in medical journals.

The small variations between species, especially between animals and man, was a most significant finding of the research, because it made a large amount of previous work on animals pertinent to man. This remarkable similarity permitted the establishment of criteria for the study of the effects of shearing stress and trauma. Thus, the study of variations is applied to the solution of surgical problems. The research reported in the present article was combined with histological studies and showed that the structure of these tissues varies according to the function or the kind of service performed in the mechanics of the human body.

In conclusion, it is hoped that this small contribution on the strength of fibrous tissues may be but the beginning of a closer cooperation between the engineering and the medical professions to their mutual advantage.

### ACKNOWLEDGMENT

The authors wish to express their appreciation to the various departments of the College of Physicians and Surgeons at Columbia University for their kind assistance during the performance of these experiments. In addition to the medical cooperation, the work was further advanced with the cooperation of The American Society of Mechanical Engineers, while material assistance was given throughout by the Bell Laboratories, and particularly by R. L. Wegel. The engineering phase of the work was done in cooperation with G. B. Karelitz, associate professor of mechanical engineering at Columbia University.

*Underwood and Underwood*

A GENERAL VIEW OF THE MEDICAL CENTER IN NEW YORK CITY WHERE THE AUTHORS, DR. GRATZ AND DR. BLACKBERG, DID THEIR EXPERIMENTAL WORK

# OIL BURNERS *and* BOILERS

## *Their Efficient Application to Domestic Heating*

By L. E. SEELEY

YALE UNIVERSITY

IN A study relating to the efficient application of oil burners and heating boilers to domestic heating it is apparent that the peculiarities of the heating load and of heating systems must be established in addition to the performance characteristics of oil burners and heating boilers. As far as oil burning itself is concerned, problems of design, combustion, and control devices will not be especially considered in this paper. The task of burning oil automatically, safely, and efficiently has been substantially accomplished. The present object is to discover preferable adaptations of various combinations of boilers and burners to the domestic-heating load from the standpoint of fuel economy. In stressing the question of fuel economy it ought to be remembered that any final choice of equipment should be influenced by the following factors which are here listed without comment: (1) First cost of burner and boiler; (2) grade of oil used and its cost; (3) cost of electric power; (4) probable comfort to be achieved; (5) reliability and safety of equipment; (6) quality and cost of servicing; and (7) intangibles arising from personal preferences.

It is the custom to determine the heat loss[1] or net load of a building based upon certain severe weather conditions which occasionally occur. The heat loss or net load is thus the probable maximum heat loss of the building which can only take place when the weather is really severe. Under usual conditions the actual heat loss will be only a fraction of the net load.

Despite the fact that the greatest actual heat loss may never exceed the net load, it has always been recognized that the boiler should possess a capacity in excess of the net load. This capacity is commonly known as the gross load. It is determined by adding certain allowances for piping, pick-up, and fuel to the net load. There has been more or less uncertainty associated with these allowances during past years where boilers were catalogued and purchased on ratings of the gross-load type previously mentioned. Recommended allowances for hand-fired, coal-burning boilers range from 50 to 100 per cent or more above the net load, depending upon the boiler selected. A given installation should suggest some desirable gross load for satisfactory results which in itself will be practically unaffected by the boiler actually selected. A determination of allowances for a specific case should not produce the inconsistent variations mentioned.

With automatic fuel-burning devices certain difficult elements involved in the question of allowances (i.e., firing period, attendance, grade of fuel, etc.) have been eliminated, and a more rigorous basis for determining gross loads may be developed. Certain propositions should first be clear:

(*a*) If a house has cooled down for any reason at all, its heat loss is correspondingly reduced.

(*b*) Under such conditions if heat equal to the net load is supplied to the house there will be an excess of heat available for reheating the house.

(*c*) A properly proportioned heating system will emit from the radiators an amount of heat equal to the net load if room temperatures are normal and can only emit more heat if room temperatures are below normal (i.e., in a 50-deg room the radiation gives off about 18 per cent more heat than in a 70-deg room.

(*d*) The aforementioned heat emissions are thus definitely limited and do not serve to account for the gross load—this is especially true where room temperatures are kept normal by thermostatic regulation.

(*e*) Some added amount of heat would be proper to allow for heat lost from the piping, although heat lost from piping is really a less advantageous application of heat to the building rather than an absolute loss.

In view of the fact that allowances may run as high as 56 per cent above the net load,[2] it becomes necessary to determine just what factors govern the value of the gross load. Aside from piping, the excess heat seems clearly for only one real purpose and that is to heat up the heating system itself. If a building and its contents have cooled down, it is evident that the heating system itself must first be raised to operating temperature and that this heat is of no immediate value to the building. The time allowed for heating up will have a great effect upon the gross load required. For satisfactory heating service the time allowed to get the heating system to operating temperature is naturally limited.

It follows that the gross load will be highest where the weight of the heating system is greatest. The use of light radiators will reduce the gross load and yet give the same heating performance. Warm-air and air-conditioning systems weigh comparatively little and the gross load may approach the net load. If the method of operation allows the heating system to cool off periodically then the gross load is required every time that reheating is required. By the same token if the heating system is kept warm continuously, then the gross load could be considerably reduced. Practically, this latter is not quite so important because it makes no allowance for a possible breakdown or service interruption in very cold weather and would result in a longer heating-up period.

It should be clear at this point that the gross load is influenced by the nature of the heating system or more specifically by its weight and also by the manner of supplying heat to the system (viz., continuously or intermittently). Theoretically, with a continuous but graduated supply of heat the gross load need only exceed the net load by the amount required for piping or its equivalent, regardless of the type of heating system. Once this gross load is determined it is necessary to choose a boiler and burner that will produce the load required.

Test data, derived from a cooperative test program by the

[1] Based on inside and outside temperatures; size, location, and materials used in structure; wind, etc. See Chapters 5, 6, and 7, 1934 Guide, A.S.H.&V.E.

Contributed by the Fuels Division and presented at the Annual Meeting, New York, N. Y., December 3 to 7, 1934, of The American Society of Mechanical Engineers.

[2] Recommendation of the American Gas Association, see Table 1, p. 394, 1934 Guide, A.S.H.&V.E.

American Oil Burner Association, Yale University, and the American Society of Heating and Ventilating Engineers,[3] and published by the last-mentioned, reveals that the selection must be made with regard to the type of oil burner being used if fuel economy is to be obtained. For the purpose of this study oil burners will be classified according to methods of regulating the fuel-burning rate, as follows: (*a*) intermittent, (*b*) high and low, and (*c*) graduated.

The intermittent burner has only one fuel-burning rate. It

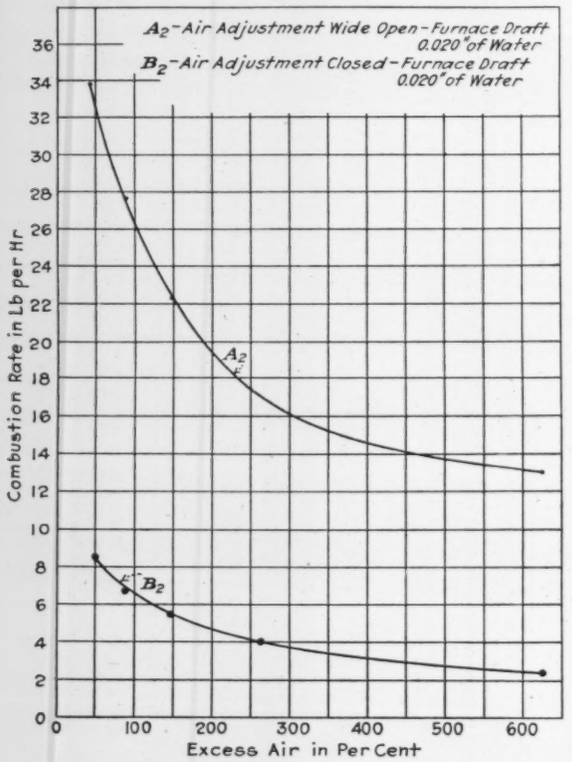


FIG. 1 FUEL-BURNING RATES VS. PER CENT OF EXCESS AIR

operates at this rate or not at all. The high and low, as its name suggests, has two fuel-burning rates and it operates continuously at one rate or the other. The graduated burner may have a dozen fuel-burning rates. By slight changes this burner, operating continuously, can supply the heat loss approximately as it takes place.

In order to appreciate the final implications regarding selection of equipment, it seems best to deviate sufficiently to develop a general background of oil-burner and heating-boiler behavior. As to oil burners generally, it may be said that they are devices for preparing, mixing, and igniting controlled quantities of air and fuel. Mixing may be further assisted by the design of the furnace. If an oil burner in practice can burn the oil completely with a moderate excess (i.e., 50 per cent) of air and without smoke, it is doing a commendable job.

The possible range of operation as to fuel-burning rates and excess air is shown by Fig. 1. Curve $A_2$ represents the maximum fuel-burning rates of a certain oil burner at various proportions of excess air. Curve $B_2$ shows the minimum rates. It shows that at 50 per cent excess air (or 10 per cent $CO_2$) the burner has its widest range of fuel-burning adjustments. It suggests that the combustion must generally be good if a burner is pushed to or near its maximum fuel-burning rate. It also shows that very low fuel-burning rates can be accomplished only by increasing the excess air. This latter indicates what may be expected from high and low burners at the low burning rate or from the graduated type at lower fuel burning rates. The effect of excess air on boiler efficiency is shown by Fig. 2.

If a number of oil burners are installed successively in one boiler and every burner adjusted to show the same excess air (i.e., 50 per cent) and if the furnace draft is kept the same (i.e., 0.02 in. of water) in all cases, Fig. 3 shows that the efficiencies obtained will not be the same in all cases. The most striking difference in the burners is the size, shape, and location of the flame. Radiation in the furnace or firepot and heat losses from the boiler will vary. In support of this explanation, Fig. 4 shows two oil-burner curves *OB*4 and *OB*8 and one gas-burner curve *GB*1 all obtained by tests in the same boiler. These burners gave flame positions and other characteristics as nearly the same as could be obtained and the results agree more closely than those of Fig. 3.

Curves shown by Fig. 3 were obtained by a series of tests run at various fuel-burning rates and standard[4] operating conditions

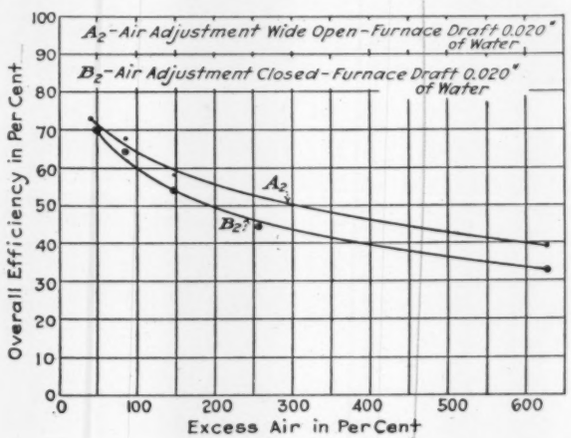


FIG. 2 OVERALL EFFICIENCY VS. EXCESS AIR

(i.e., 10 per cent $CO_2$ or 50 per cent excess air, and 0.02 in. furnace or firepot draft). If one fuel-burning rate is chosen and different average outputs obtained by running the burner intermittently, an intermittent efficiency curve can be obtained. Curve *A*, Fig. 5, is the one obtained by the first-mentioned conditions and curve *B* the one obtained by intermittent tests. Curve *B* is typical of intermittent and high and low burners. The efficiency is always highest at the point where the burner operates continuously (see point *x*, Fig. 5). If the output at point *x* represents the gross load, then curve *B* indicates the economy at various average outputs below the gross load. If point *x* is a proper gross load, then curve *C* (not a test curve but similar in shape to *B*) indicates the possible loss in economy due to an unnecessarily high gross output (i.e., point *Y*).

[3] "Study of Performance Characteristics of Oil Burners and Low-Pressure Heating Boilers," by L. E. Seeley and E. J. Tavanlar, *Heating, Piping, and Air Conditioning*, May, 1931.
"Study of Intermittent Operation of Oil Burners," by L. E. Seeley and J. H. Powers, Ibid., February, 1932.
"Air Supply and its Effect on Performance of Oil Burners and Heating Boilers," by L. E. Seeley, J. H. Powers, and E. J. Tavanlar, Ibid., December, 1932.
"Comparison of Oil and Gas Firing in a Heating Boiler," by L. E. Seeley and E. J. Tavanlar, Ibid., October, 1933.
"Study of Fuel Burning Rates and Power Requirements of Oil Burners in Relation to Excess Air," by L. E. Seeley and E. J. Tavanlar, Ibid., May, 1934.

[4] Standard, so-called, for the tests in question; there is no official standard.

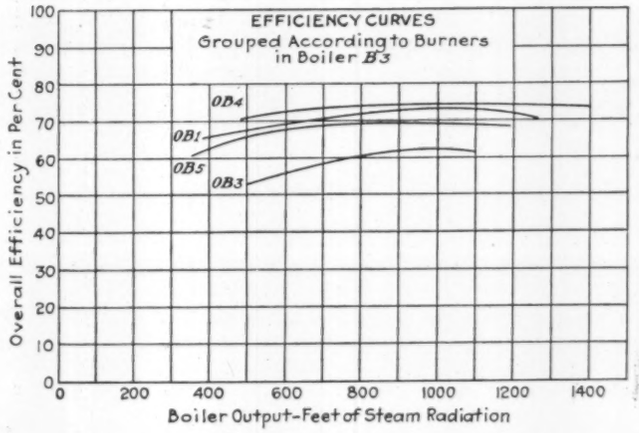


FIG. 3 OVERALL EFFICIENCY VS. BOILER OUTPUT

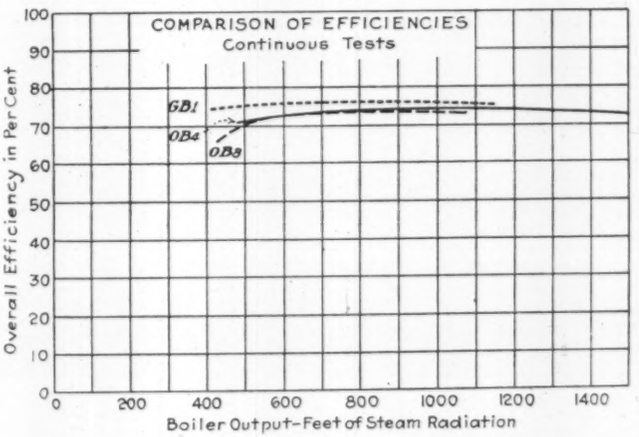


FIG. 4 OVERALL EFFICIENCY VS. BOILER OUTPUT

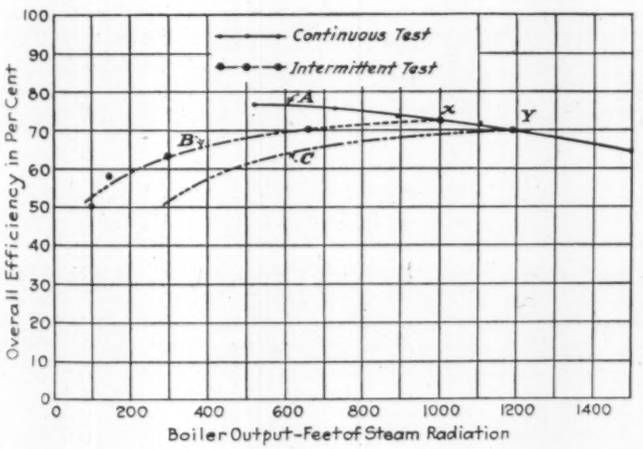


FIG. 5 OVERALL EFFICIENCY VS. BOILER OUTPUT

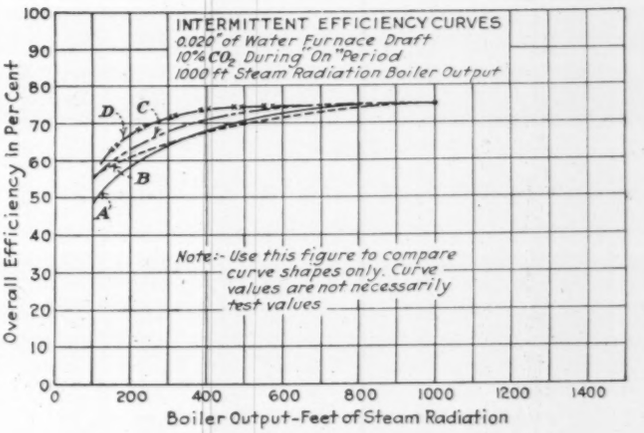
INTERMITTENT EFFICIENCY CURVES
0.020" of Water Furnace Draft
10% CO2 During "On" Period
1000 ft Steam Radiation Boiler Output
D
C
B
A
Note:- Use this figure to compare curve shapes only. Curve values are not necessarily test values
Overall Efficiency in Per Cent
Boiler Output-Feet of Steam Radiation

FIG. 6 OVERALL EFFICIENCY VS. BOILER OUTPUT

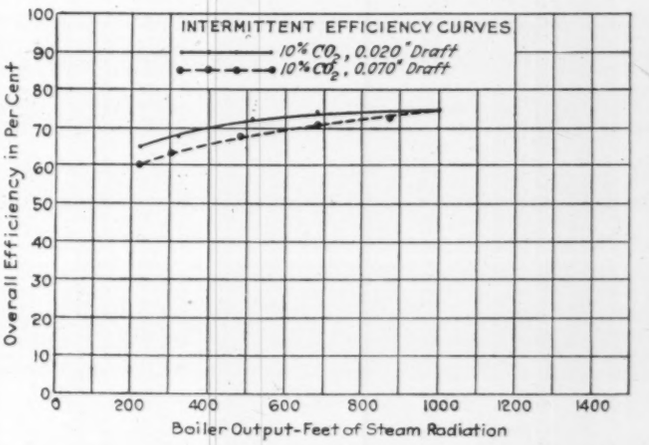
INTERMITTENT EFFICIENCY CURVES
10% CO2, 0.020" Draft
10% CO2, 0.070" Draft
Overall Efficiency in Per Cent
Boiler Output-Feet of Steam Radiation

FIG. 7 OVERALL EFFICIENCY VS. BOILER OUTPUT

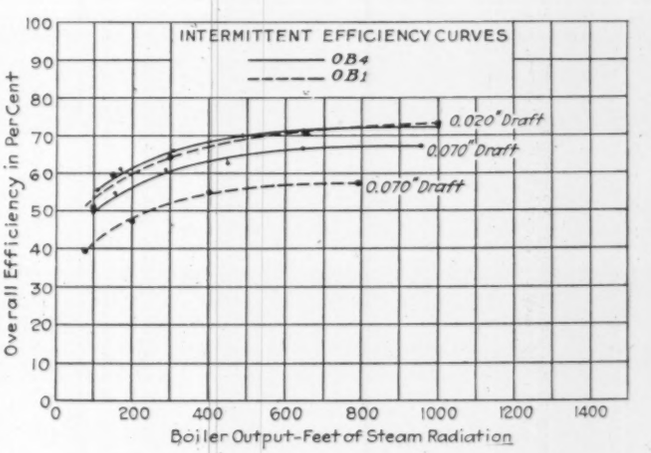


FIG. 8 OVERALL EFFICIENCY VS. BOILER OUTPUT

If a number of burners were capable of giving the same output and efficiency while operating continuously it would still be possible for the economy to vary during intermittent operation (see Fig. 6). These curves were shifted arbitrarily to show the same output and efficiency during the "on" or operating period in order to contrast the curve shapes more effectively. These differences may be explained by considering the effect of intermittent operation. As soon as a burner shuts off, an air-cooling period commences. More or less air flows through the burner into the furnace during the "off" period, depending upon burner design. This carries away heat stored up in the furnace and boiler. The flow of air is restricted by some burners and not by others. The effect on off-period losses is obvious. It should be noted that furnace-draft adjustments were the same in all these cases.

To substantiate the foregoing explanation, a burner was ad-

justed to produce a certain output with 50 per cent excess air in one case with a furnace draft of 0.02 in. of water and in the other with 0.07 in. of water. The efficiency during the "on" period was the same in both cases, but Fig. 7 shows that where the draft was 0.07, the average efficiency was lower due to greater air leakage into the boiler during the "off" periods.

Along the same vein, Fig. 8 shows what happens to burners if the furnace draft only is changed from 0.02 to 0.07 in. of

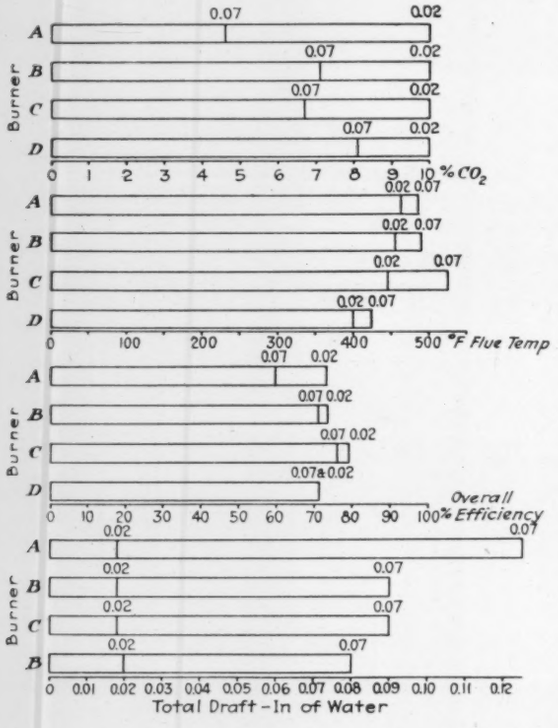


FIG. 9 EFFECT OF CHANGE IN FURNACE DRAFT FROM 0.020 TO 0.070 IN. OF WATER—COMBUSTION RATE CONSTANT IN EACH CASE

water. In the first place it appears that some burners are more susceptible to changes in furnace draft than others. More air enters the furnace for a given change in draft in one case than the other. The importance of maintaining furnace draft constant is evident especially for "susceptible" burners. It is true that boiler design can also inhibit or prevent the escape of highly heated gases during the off-period. Ordinarily, draft regulation may be achieved by one of several devices of a check-damper type and it is usually advisable to use such a device.

The various effects of a change in draft may also be shown by Fig. 9 for a number of burners, designated as *A*, *B*, *C*, and *D*. The pertinent distinction regarding these burners relates to the method of air supply, as follows:

Burner *A:* Air induced by natural draft through an orifice adjusted at the time of installation.

Burner *B:* Primary air supplied by fan and secondary air supplied through an orifice by natural draft.

Burner *C:* Similar to *B*.

Burner *D:* Entire air supply from fan at relatively high pressure.

Generally, it appears that an increase in furnace or firepot draft increases the excess air, the flue temperature, the draft loss through the boiler and decreases the efficiency. The susceptibility of burner *A* to draft fluctuations compared to burner *D* is quite evident. Burners *B* and *C* properly occupy the middle ground. The burner designations apply to Fig. 6.

In Fig. 10, curve *A* shows the efficiency obtained under standard operating conditions (i.e., 50 per cent excess air and 0.02 in. of water furnace draft) and curve *C* shows the intermittent efficiency. Curve *B* indicates what a graduated type burner will do. If the graduated burner is operated under standard conditions then curves *B* and *A* will coincide, but at lower fuel-burning rates, in actual practice, the excess air actually increases. This results in curve *B* gradually dropping away from *A*.

It appears that the gross load with an intermittent burner will be influenced by the weight of the heating system, but that it would be unwise to make the value any larger than necessary. Furthermore, the best boiler to use in this case will give it highest efficiency at the gross load. No other arrangement can be better.

With a graduated burner it should not be necessary to provide for as high a gross load because of steady heat. Furthermore, the best boiler will have its maximum efficiency at an output about one-half of the net load because the burner will operate more hours at that output and will seldom operate at its maximum capacity.

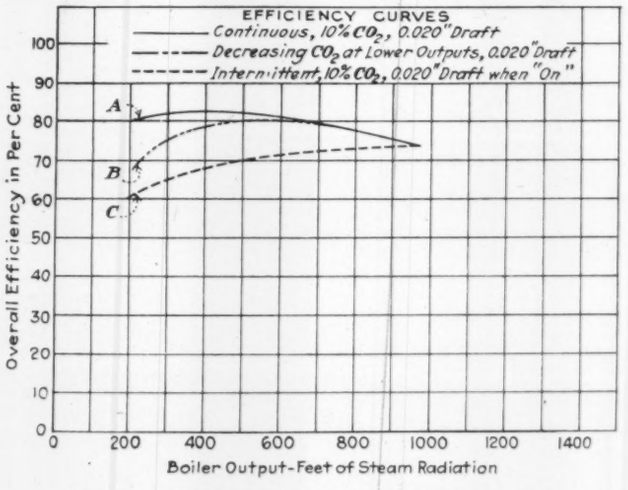


FIG. 10 OVERALL EFFICIENCY VS. BOILER EFFICIENCY

Thus for the same home, depending upon the method of fuel-burning, one boiler may have its maximum efficiency at about 50 per cent below net load while the other may require its maximum efficiency at about 50 per cent above net load. If maximum efficiency occurs in both cases at a heat-absorption rate of 3000 Btu per sq ft of heating surface per hour, then it follows that one boiler would be three times as large as the other as far as heating surface is concerned.

These comparisons are based on outside figures. Actually in the case of light-weight heating systems the gross loads would not be very different in any case and the important factor would be the output at which maximum boiler efficiency should be achieved. The novelty in the findings may be best appreciated by pointing out that, traditionally, heating boilers were not generally designed to produce maximum efficiency at the maximum or gross load. This is a proper procedure where fuel is continuously burned (see Fig. 10, curve *B*) but with intermittent fuel-burning a different basis of design is clearly required.

Finally, it should be evident that the above findings will apply to any fuel, solid, liquid, or gaseous, where the fuel-burning rates are intermittent, high and low, or graduated. The only improvement that a more rational selection and adjustment of equipment will produce will be a decrease in fuel costs and nothing more.

# *Deflection of a*
# LONG HELICAL GEAR TOOTH

By CHARLES W. MacGREGOR

CAMBRIDGE, MASS.

THE prediction of the magnitudes of the elastic deflections of long helical gear teeth under actual loading conditions is a comparatively difficult task. Various factors, such as the profile shape of the tooth, the manner in which the load is distributed over the contact area, and the helical curve along the length of the tooth, complicate the problem. Considerable useful information may, however, be obtained for the design of such gears by computing the deflection of the special case of a long cantilever plate of rectangular profile loaded by a single concentrated force $P$, perpendicular to the plane of the plate, as indicated in Fig. 1. This problem can be solved by means of the mathematical theory of elasticity. In addition, further information may be obtained by measuring the deflections in actual cases by means of a specially designed model apparatus. In this discussion, first the exact solution of the problem outlined in Fig. 1 will be briefly described, and second, the results of a few tests made to check the calculations will be given.

## THEORY

The solution of the problem indicated can be established by applying the theory of flat plates to the long cantilever plate shown in Fig. 1. It will be assumed that: (1) The long sides of the plate $x = 0$ and $x = a$ extend to infinity; (2) the plate is rigidly clamped along $x = 0$; (3) the deflection of the plate is small compared to its thickness; (4) it is loaded by a force $P$ acting perpendicularly to the plane of the plate and concentrated in a single point situated along the outer edge $x = a$; and (5) that the thickness $h$ is small compared with the width $a$. Although this last assumption cannot be true for actual gear shapes where $h$ and $a$ are quantities of equal order of magnitude, the case mentioned may still furnish the major portion of the deflection, as must be concluded from analogous cases in the theory of bending of short bars. In addition, if necessary, the effect of shear on the deflection can easily be computed and added to the following deflections obtained from the theory of the bending of flat plates.

Under these considerably simplifying assumptions, the problem is reduced to that of finding the deflection $w = f(x, y)$ of this plate from solutions of the bi-harmonic equation

$$\nabla^2\nabla^2 w = 0 \quad \ldots\ldots [1]$$

where $\nabla^2$ is the Laplacian operator in two dimensions. The boundary conditions to be satisfied are, for $x = 0$, the deflection and slope are zero, and for $x = a$, the bending moment $m_x$ in the $x$ direction per unit of length is zero and the total shearing or reaction force per unit of length on the face $x = a$ is a certain function of $y$.

The deflection $w$ can then be represented by a Fourier integral of the form

$$w = \int_0^\infty \mathbf{X}(\alpha x) \cos \alpha y \, d\alpha \quad \ldots\ldots [2]$$

where $\mathbf{X}(\alpha x)$ consists of four terms containing hyperbolic functions with four constants to be determined from the aforementioned boundary conditions. After these four constants have been thus determined[1] and substituted in Equation [2] we get the deflection $w$ in the form

$$w = \frac{4Pa^2}{\pi N} \int_0^\infty f(\lambda) d\lambda \quad \ldots\ldots [3]$$

where $\lambda = 2\alpha a$, and $f(\lambda)$ is different for each point $(x, y)$ of the plate. The quantities $f(\lambda)$ for each point chosen were then plotted as functions of $\lambda$. The areas under these curves were obtained by graphical means from $\lambda = 0$ to a sufficiently large value of $\lambda$ such that the function itself could then be

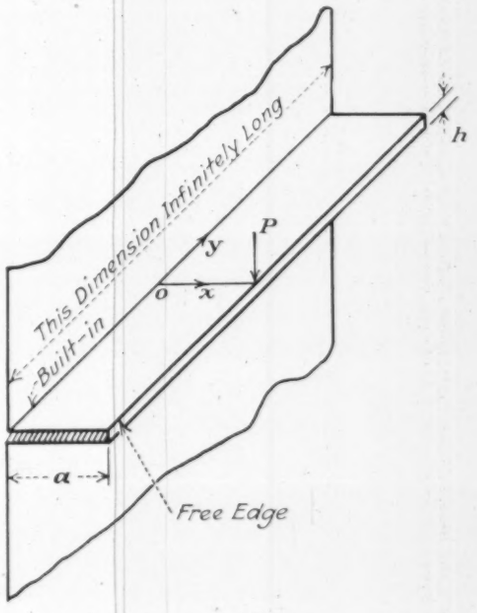


FIG. 1 LONG CANTILEVER PLATE LOADED BY CONCENTRATED FORCE $P$

replaced by a simpler expression, and the remaining areas under the curves to $\lambda = \infty$ could be determined analytically.[2] The calculation was carried through for steel as plate material. The deflection was thus evaluated for points along the free edge of the plate at $y = 0$, $a/4$, $a/2$, $a$, $2a$, and $2.5a$. In this manner the deflections at these points may be represented by the simple formula $w = K\ (Pa^2/\pi N)$, where $N$ is the plate-

[1] The general integral expression for the deflection at any point of the plate is rather complicated and will be omitted here. For details of this calculation of "Selected Problems in the Theories of Flat Plates and Plane Stress," Dissertation, University of Pittsburgh, 1934.

[2] This method of evaluation of integrals has been used extensively in "Über die Biegung der rechteckigen Platte durch Einzellasten," by A. Nadai, *Der Bauingenieur*, vol. 11, 1921, pp. 299–303.

TABLE 1 DEFLECTION OF FREE EDGE OF PLATE ALONG $x = a$

| Distance from point of load application along $x = a$ | Factor $K$ |
|---|---|
| 0 | 0.527 |
| $a/4$ | 0.470 |
| $a/2$ | 0.380 |
| $a$ | 0.213 |
| $2a$ | 0.0496 |
| $2.5a$ | 0.0385 |

rigidity factor and the values of $K$ are given in Table 1.

The maximum bending stresses at the point (0, 0) in the outside fibers were also computed and found equal to

$$\sigma_x = \pm \frac{6m_x}{h^2} = \pm \frac{3.048P}{h^2}$$

$$\sigma_y = \pm \frac{6m_y}{h^2} = \pm \frac{0.9162P}{h^2}$$

$$\tau_{xy} = \pm \frac{6m_{xy}}{h^2} = 0$$

where $\sigma_x$, $\sigma_y$, and $\tau_{xy}$ are the bending stresses in the $x$ and $y$ directions, and the shearing stress in the $(x,y)$ plane, respectively.

## EXPERIMENT

In order to provide a check on the large amount of numerical work carried out in the calculation of the deflections along the edge of the cantilever plate already discussed, an experimental apparatus was constructed which fulfils as closely as possible the requirements regarding the fundamental assumptions of the plate theory. This apparatus was constructed as shown in Fig. 2. The details are more clearly shown in the side and front views, Fig. 3. The cantilever plate testing apparatus consists essentially of a steel block having two carefully machined and ground flanges on both sides, a loading frame with knife edges, a clamp and steel pin for applying the load to each flange, and a pair of Huggenberger tensometers for measuring the deflections. The essential dimensions are shown in Fig. 4. The fillets at the built-in end have a radius of $^1/_{32}$ in. which provides a well-determined length of plate and

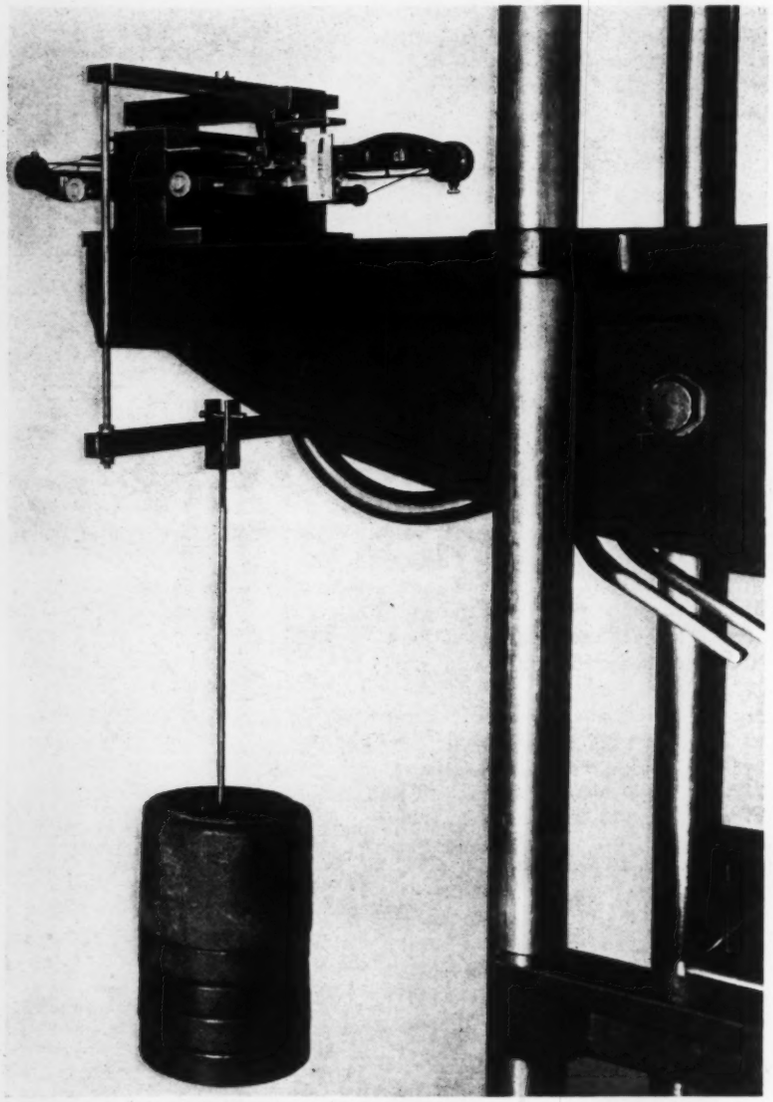

FIG. 2 PLATE-TESTING APPARATUS

at the same time produces a stress-concentration factor[3] of only 2.

The procedure in testing was merely reading the tensometers at one position for a certain small initial load, then adding weights which were accurately calibrated (±0.01 pound) and reading them again at a higher load, and the difference of the readings under the two different loads gave the deflection produced by the additional load. The tensometers were then shifted to a new position, the location of the load being kept the same, and the process repeated. In this manner the deflection curve of the entire free edge under the same concentrated load was obtained.

The deflection curve of the free edge so determined was then plotted as shown in Fig. 4. The deflection curve for this same plate was then calculated by means of the previously developed plate theory, and plotted in the same diagram. For this latter calculation the value of $E$ was determined by experiment to be $30 \times 10^6$ lb per sq in. and Poisson's ratio was assumed equal to 0.3 for steel. Comparing the theoretical curve with the one determined experimentally, it is seen that the agreement is very close. The experimental values were only slightly larger than those obtained theoretically, agreement being within 2.5 per cent.

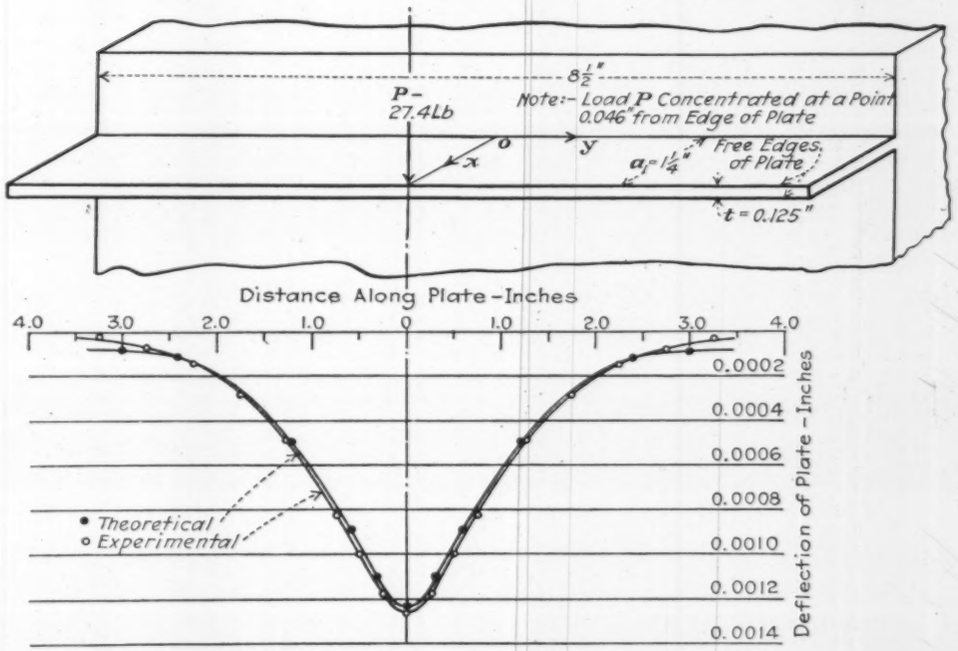


FIG. 4 COMPARISON OF THEORETICAL AND EXPERIMENTAL DEFLECTION CURVES ALONG EDGE OF CANTILEVER PLATE (RATIO $a_1/t = 10$)

Tests were also made by A. M. Wahl and the author on shorter gear teeth in which the effect of diagonal loading was investigated. The method of superposition was found to work very well for these cases.

[3] "Strength of Materials," by S. Timoshenko, New York, D. Van Nostrand Co., vol. 2, 1930, p. 618.

ACKNOWLEDGMENT

The author wishes to express his appreciation to A. Nadai for his valuable aid during the progress of this investigation and to acknowledge his indebtedness to the Westinghouse Research Laboratories, in particular to L. W. Chubb, R. E. Peterson, and A. Nadai, for providing the opportunity of carrying through the experimental portion of this work.

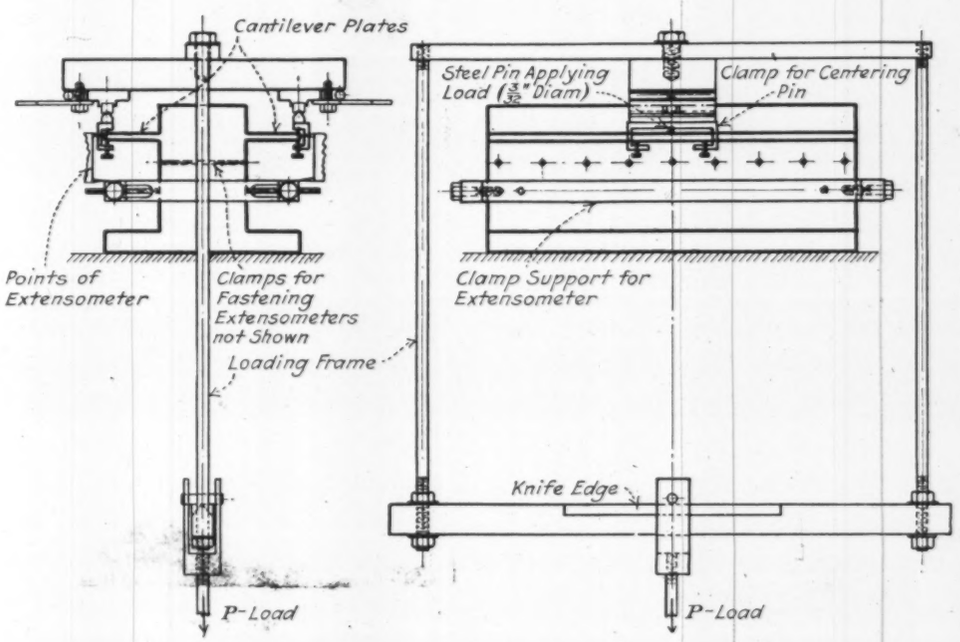


FIG. 3 SIDE AND FRONT VIEWS OF CANTILEVER-PLATE-TESTING APPARATUS

# *Study of the* FLOW *of* AIR *with a* STROBOSCOPE

By HAROLD E. EDGERTON

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

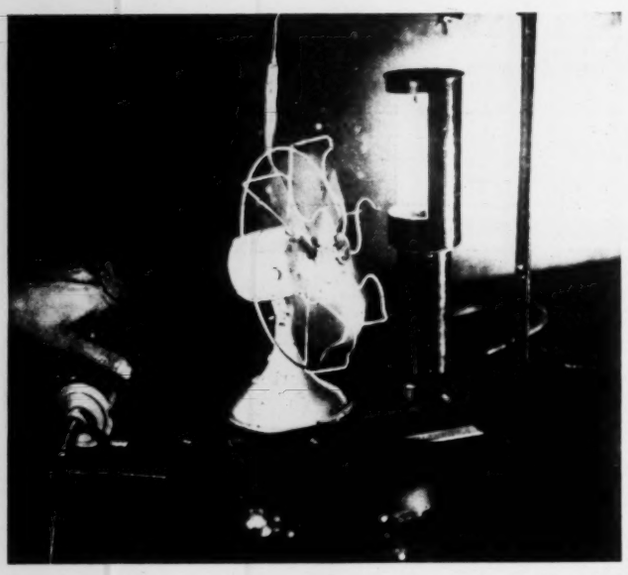

FIG. 1 MERCURY-ARC STROBOSCOPE TUBE ARRANGED TO ILLUMINATE AN ELECTRIC FAN

AN IMPORTANT engineering application of the stroboscope which is not in general use is to study the flow of air as it passes through the blades of a fan. The information gained by such studies should be valuable to engineers who design and use fans. The filaments of air are made visible by using smoke, which shows clearly the action of the air as it stretches and swirls into vortices from the tips of the blades. A very real impression of the action is conveyed to the observer, since he sees the fan blades apparently going very slowly and the filaments of air also passing slowly through their various phases of action.

Titanium tetrachloride, the chemical used to produce dense white smoke screens for war purposes, is a convenient material for making filaments of air visible. The formula for this light-yellow liquid material is $TiCl_4$ and it reacts when exposed to air to give titanium dioxide ($TiO_2$). Titanium-dioxide particles are very small and therefore they follow the flow of the air in which they are formed. A convenient method of introducing the smoke into a stream of air is to saturate a small wad of cloth or cotton on the end of a wire, suspending the saturated cloth in the stream of air at the desired position.

An illusion is produced by the stroboscope when properly adjusted so that motions of a repetitive nature, such as this, are apparently slowed down, stopped, or even made to run backward.

Fig. 1 shows a mercury-arc stroboscope tube arranged to illuminate an electric fan. An adjustable-speed contactor is located on the left side of the photograph and is being adjusted so that the frequency of the light flashes and the speed of the fan correspond.

Fig. 2 is an enlargement of two frames from a motion-picture film showing vortices formed by air as it passes through the blades close to the tips. The motion-picture camera was operated at a speed so that each frame was exposed by several light flashes from the stroboscope in order to prevent any variation in exposure. Supersensitive panchromatic film was used and pictures were taken with a f3.5 lens.

The remaining photographs were taken with a single flash of light of much larger power than is generally used for stroboscopic observation in order to obtain pictures with detail. The exposure time was about $1/_{100,000}$ of a second.

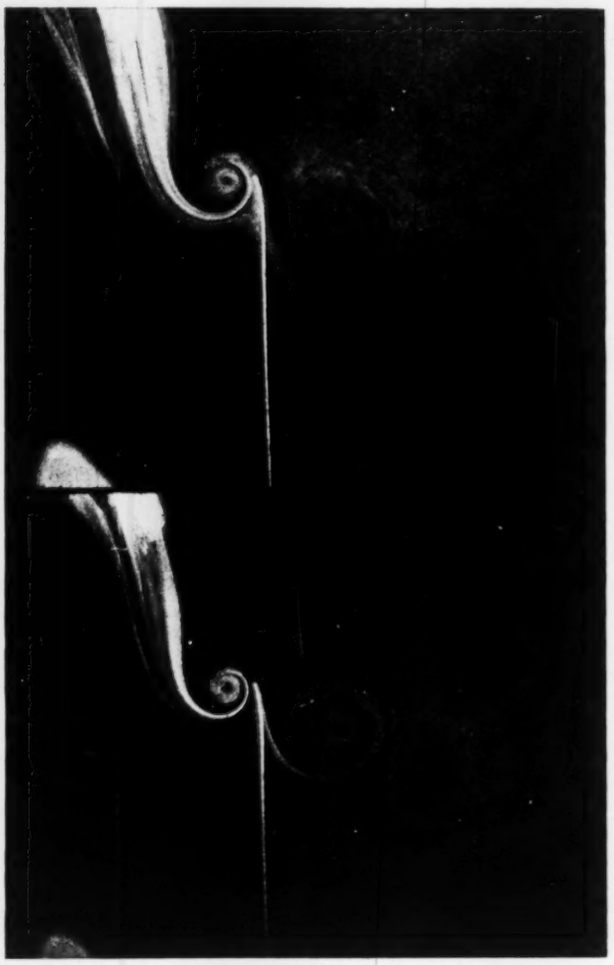

FIG. 2 VORTICES FORMED BY AIR PASSING THROUGH FAN BLADES AS REVEALED BY THE STROBOSCOPE AND CAMERA

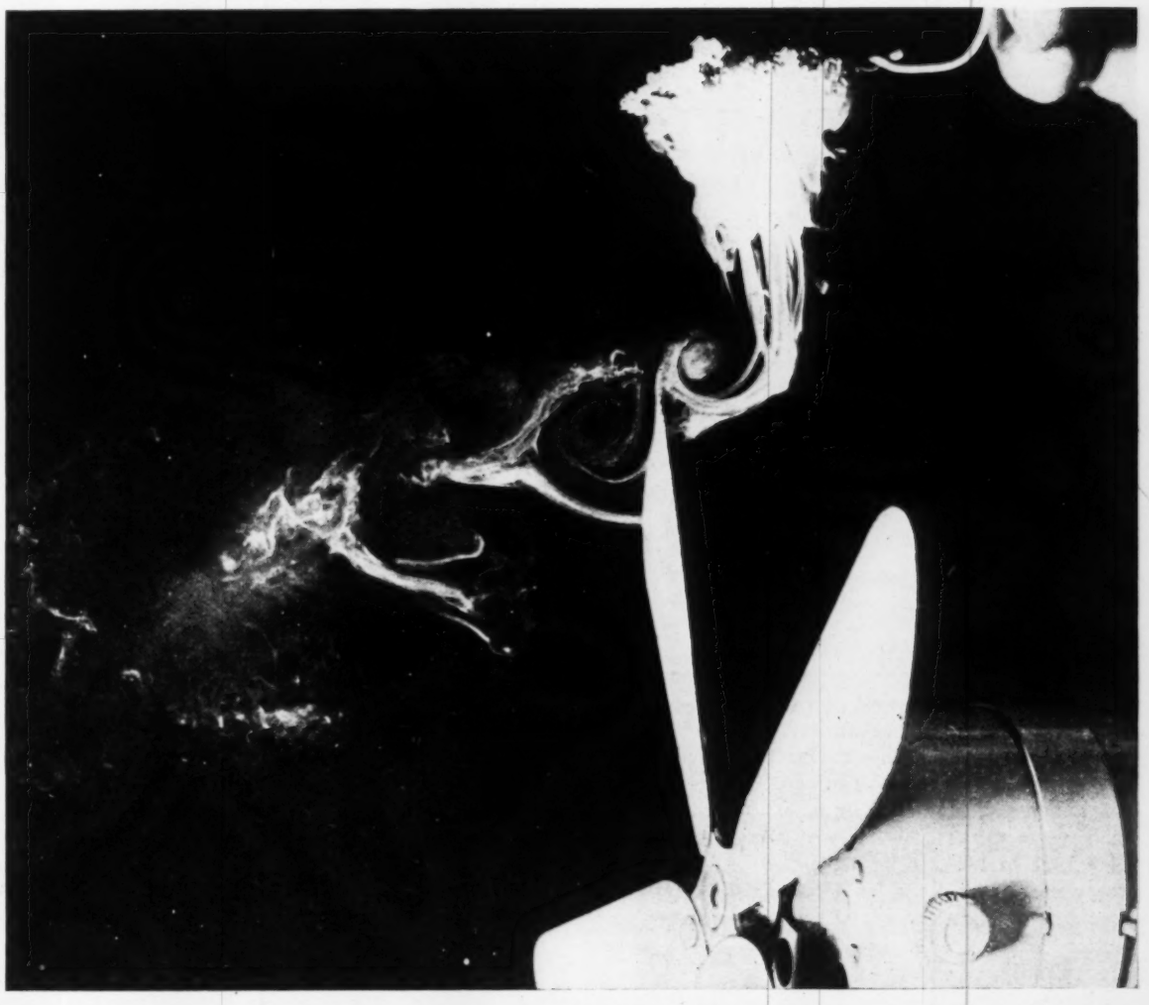

FIG. 3 AN INSTANTANEOUS PHOTOGRAPH OF VORTICES IN AIR AT TIP OF FAN BLADE

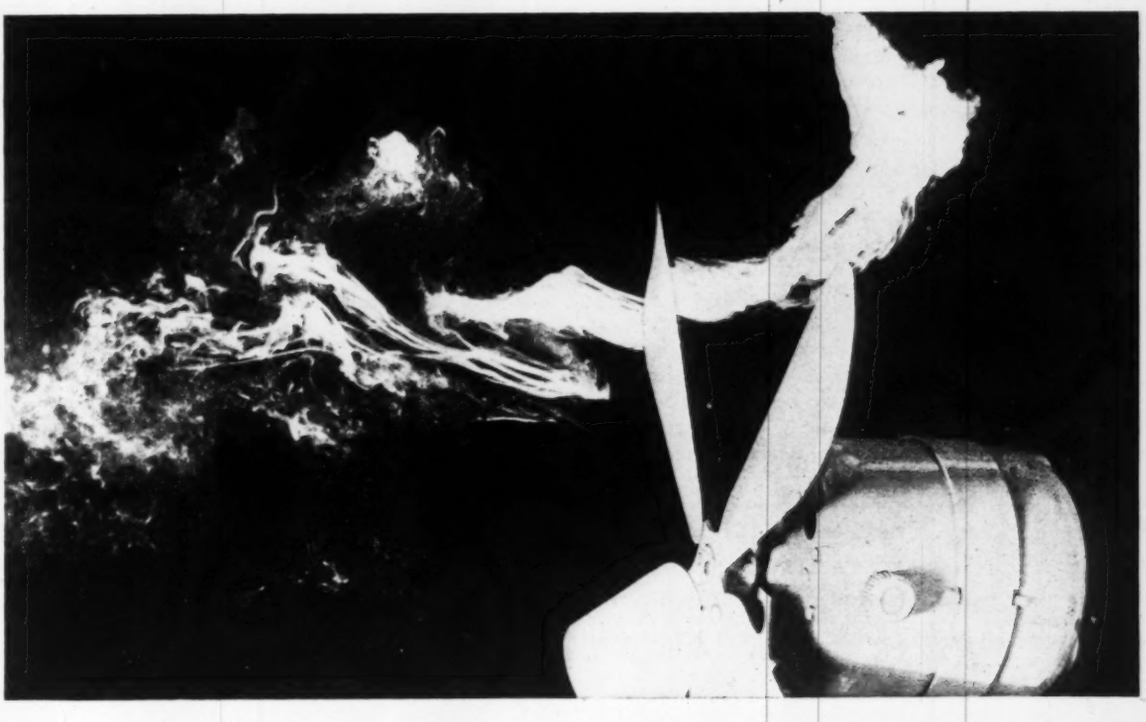

FIG. 4 FLOW OF AIR THROUGH FAN BLADES AS REVEALED BY THE HIGH-SPEED CAMERA

# *Prevention of*
# OCCUPATIONAL DISEASES
## *Other Than Those That Are Caused by Toxic Dust*

By R. R. SAYERS and J. M. DALLAVALLE

UNITED STATES PUBLIC HEALTH SERVICE

THE USE of volatile chemicals has increased greatly during the past few years. They have become indispensable in the manufacture of paints, in dry-cleaning processes, and as solvents in various industrial processes, to mention but a few of their common uses. In fact, so great has been the demand for volatile solvents both by industry and the general public, that new applications for them are constantly being developed and commercialized. The volatile solvents perform a large and important part of industrial expansion into new fields as new uses for them are discovered.

Partly as the result of the increased use of new chemicals in industry, it is now well recognized that the hazards of certain occupations are important factors in the causation of sickness and even death. Dublin (1)[1] has evaluated the effect of the industrial environment on the well being of a large number of workers in a mortality study among more than three million white, male wage earners. The study covered a three-year period from 1922 to 1924, inclusive, and is compared with a similar study made over a similar period from 1911 to 1913. The groups studied constituted a fairly representative social and economic class and were considered as an urban earning population. Dublin has shown by an analysis of the data obtained, that adult males engaged in industrial pursuits had a higher mortality and a shorter longevity than those in other types of work such as professional, clerical, etc. In the more recent study, it was further shown that the mortality rates for the industrial workers were more than double the rates for the non-hazardous occupations. In terms of life expectancy, the picture presented was impressive. The industrial worker at the age of 20 had an expectancy of 42 years as compared with the normal of 49 years. In other words, the life of the industrial worker in 1924 was shortened by approximately seven years, while the data for 1911 to 1913 showed the decrease in longevity to be even greater. Considering the characteristics of the groups studied, Dublin was led to the conclusion that in the industrial environment, exposure to abnormal conditions such as toxic dusts, vapors, fumes and gases, radiant heat, etc., explains the difference in longevity between industrial and non-industrial workers. Since, furthermore, there are some 900 separate occupations with exposure to occupational-disease hazards (2), the magnitude of the preventive problem should merit considerable attention.

Several methods are at present available for the prevention of occupational diseases due to exposure to substances which are injurious to health. Some of these methods have already been extensively discussed in the literature of industrial hygiene with reference to dust hazards, and, in general, the ideas there formulated have a very general application in other related fields. Briefly, these methods of prevention include: (*a*) sanitary and occupational surveys; (*b*) mechanical and personal methods of controlling a hazard at the point of origin; and (*c*) periodic medical examinations and surveys. Each of these methods is discussed in the paragraphs which follow.

### SANITARY AND OCCUPATIONAL SURVEYS

*Sanitary Surveys.* No estimate of a hazard can be made until the conditions of the worker's environment have been evaluated. In studies made by the Public Health Service (3) it has been customary, as a first step in its field investigations, to make detailed sanitary surveys. These surveys include a study of the various items with which the worker comes in daily contact. The sanitary survey is, in other words, an "inventory" of all the hygienic items which enter into the worker's environment, the manner in which he conducts his work, and the length of time he spends at each task. As a rule, such a study is carried out for each room and for the various occupations in a given plant. This procedure, when completed, gives at once pertinent information as to the types of hazards which are likely to exist and the number of workers which may possibly be affected.

The items which enter into a sanitary survey should include the following:

(1) Physical characteristics of building and room in which the survey is made: construction of building; location and size of room; number of workers; type of illumination; type of ventilation.
(2) Sanitary facilities for workers: refuse cans; cuspidor and sweeping service; washing facilities; type of toilets; drinking-water facilities; eating facilities; type of care and maintenance given to sanitary facilities.
(3) Hazards: safety hazards; dust, vapors, fumes, or gases present; exposure of workers to any sources of radiation or to abnormal temperatures.
(4) Analyses of types of employment: list of various operations and number of workers employed in each; materials handled; absenteeism and labor turnover.
(5) Preventive methods in use: isolation methods; local exhaust and general ventilation; personal respiratory-protection apparatus.
(6) Medical services: type of medical service provided and records kept; periodic medical examinations.

It may be seen from the foregoing list of items that a fairly complete picture of the conditions existing in a plant is recorded. A record of the existence or non-existence of any item at once helps the investigator to form a general conception of the line of study which must be adopted. It further makes available to him a detailed amount of information which is extremely useful. Such a survey may indicate whether or not there is compliance with various state factory or other industrial codes. For example, on the basis of the number of employees found in a given room, it may be determined whether

[1] Numbers in parentheses refer to similarly numbered references at the back of the paper.

Contributed by the Safety Committee and presented at the Annual Meeting, New York, N. Y., December 3 to 7, 1934, of The American Society of Mechanical Engineers.

there is ample per capita space, or whether sufficient toilets have been provided.

*Occupational Analysis.* Following the sanitary inspection of a plant, it is then necessary to study the various occupations. The occupational analysis includes an extensive study of the workers' immediate environment wherever a hazard is found to exist. It also entails a correlative study of the health of the workers. One is supplementary to the other and the omission of either cannot be expected to yield results which can be considered satisfactory. The Public Health Service in all its field investigations has attempted by such a procedure to establish what may be considered the safe conditions under which workers may be exposed indefinitely without injury to health. Two examples of the methods used will aptly illustrate the technique employed in making occupations surveys.

In a study of chromium-plating hazards, Bloomfield and Blum (4) examined 23 men, four of whom were not chromium platers and were selected as controls. Five other workers were not actually engaged in chromium plating, but were engaged at various duties at a distance of about ten feet from the plating tanks. The length of service of the workers was carefully determined from the individual occupational histories and varied from zero to seven years.

Since some of the workers were affected by acid mist, it was important to obtain data on the severity of the exposure. Accordingly, determinations of the amount of chromium mist present in the atmosphere were made. The amounts found varied from less than 1 mg to about 56 mg of chromic-acid mist per 10 cu m of air. The tabulated results showing the period of employment, the degree of exposure, and the findings on physical examination of the workers are given in Table 1. From an analysis of this table, it may be seen that 3 of the 19 persons employed in the plating rooms had perforated septa, 21 per cent had ulcerated septa, 47 per cent had marked inflammation of the mucosa and more than half were subject to frequent nose bleeds. From these data it is possible to discover those occupations which require immediate attention. Together with the occupational analysis, the table further shows that the safe limit of concentration of chromic-acid mist in the air is probably under 1 mg per 10 cu m of air. The occupational analysis thus often establishes the permissible limit of a contaminant for prolonged exposure.

TABLE 1 OCCUPATIONAL HISTORY AND CLINICAL FINDINGS OF WORKERS IN CHROMIUM-PLATING PLANTS

| Case No. | Occupation | Months employed in chromium-platingroom | Hours per day over tank | Approximate $CrO_3$ exposure in milligrams per 10 cubic meters | Perforated septum[1] | Ulcerated septum[1] | Inflamed mucosa[1] | Nose bleed | Chrome holes |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Chromium plater | 6½ | 4 | 15.0 | ++ | — | ++ | + | + |
| 2 | Chromium plater | 20 | 4 | 28.0 | ++ | — | + | + | + |
| 3 | Foreman plater | 7 | 2 | 25.0 | — | ++ | ++ | + | — |
| 4 | Foreman plater | 8½ | 3 | 25.0 | — | ++ | ++ | + | — |
| 5 | Chromium plater | 3½ | 4 | 56.0 | — | ++ | ++ | + | + |
| 6 | Chromium plater | ¾ | 7 | 1.2 | — | — | ++ | + | + |
| 7 | Chromium plater | ¼ | 7 | 1.2 | — | — | ++ | + | — |
| 8 | Chromium plater | 7 | 7 | 1.2 | — | — | ++ | + | — |
| 9 | Chromium plater | 3 | 7 | 1.2 | — | — | ++ | — | + |
| 10 | Chromium plater | 36 | 4 | 2.0 | — | — | ++ | — | — |
| 11 | Chromium plater | 5 | 6 | 1.2 | — | — | + | + | + |
| 12 | Chromium plater | ¾ | 6 | 1.2 | — | — | + | — | — |
| 13[3] | Chromium plater | 12 | 4 | 28.0 | — | — | — | — | — |
| 14 | Chromium plater | ⅔ | 2 | 28.0 | — | — | — | — | — |
| 15[4] | Nickel plater | 1½ | 0 | ([2]) | .. | + | + | + | — |
| 16 | Racker | 8 | 0 | ([2]) | + | — | + | + | — |
| 17 | Racker | ¾ | 0 | ([2]) | — | — | + | — | — |
| 18 | Racker | ¾ | 0 | ([2]) | — | — | + | — | — |
| 19 | Wiper | 1¼ | 0 | ([2]) | — | — | + | — | — |
| 20[5] | Foreman | 0 | 0 | 0 | — | — | + | — | — |
| 21[5] | Foreman | 0 | 0 | 0 | — | — | + | — | — |
| 22[5] | Clerk | 0 | 0 | 0 | — | — | — | — | — |
| 23[5] | Inspector | 0 | 0 | 0 | — | — | + | — | — |

[1] ++ marked; + slight; — negative; [2] Unknown; [3] Used vaseline in nose; [4] Cyanide burns; [5] Work in other departments of factory.

Frequently, it is not possible to correlate engineering and medical data in an occupational analysis. Thus, in a study of the lead hazard in a storage-battery plant (5), the Public Health Service adopted a special method of determining the permissible limit of lead dust. The investigation included a sanitary survey as outlined above and an occupational analysis which included a determination of the lead dust and fumes present in the air, a record of employment and of disabling sickness (mostly compensation cases of plumbism), physical examinations, and blood and urine analysis. The medical examinations, because of the nature of lead poisoning, were necessarily extensive. With each worker, subjective symptoms such as colic, weakness, loss of appetite, constipation, nervousness, etc., were noted. Similarly, the important objective symptoms were recorded, including pallor, jaundice, tremor, reflex and pathological changes in the blood and urine. However, although a large number of engineering and medical data were available, it was found to be inconclusive due to the large labor turnover which the plant had experienced during the course of the study. This had already been indicated by the sanitary survey, and as a result a careful record had been kept of the workers who had reported to the plant clinic for various complaints, characteristic of lead poisoning. From the knowledge of the lead concentration to which these workers had been exposed, it was then possible to estimate approximately that concentration of lead for which a minimum number of workers had found it necessary to visit the clinic. Hence, except for prolonged exposure, it was shown in this manner that the safe limit of exposure of lead dust and fumes was less than 1.5 mg per 10 cu m of air.

The foregoing examples show the importance of a carefully conducted occupational analysis. Not all conditions found in practice can be similarly treated, but a few facts stand out and are generally common in most surveys of occupational-disease hazards; these are: (*a*) a detailed list of occupations and the number of workers exposed; (*b*) a careful occupational history of each worker. This is most important as has already been pointed out with regard to dust hazards (6), but it is equally applicable to all types of hazards. The occupational history which is a list of all the previous occupations of the worker and his time spent in each is frequently of great assistance in diagnosing ailments which may not be entirely attributed to his present work; (*c*) physical examinations of all workers with particular emphasis on the characteristic symptoms of the contaminant to which they are exposed. Careful present and past medical histories must also be taken; (*d*) quantitative determinations of the contaminant present in the air; and (*e*) a correlative analysis of the medical and engineering findings with a view to establishing threshold or safe limits of exposure.

*Threshold Limits.* Thus far the steps necessary to evaluate a given hazard have been outlined. It is clear that the starting point of a preventive program hinges upon the safe limit of air contamination which the worker may breathe continuously without injury to his health. Unfortunately, extensive field studies of the type discussed above have been few and there are still many practical data wanting. However, both in this country and abroad, laboratory experiments have been carried out on animals and humans, and it has been possible to determine approximately the safe limit of exposure to various sub-

TABLE 2 PHYSICAL AND TOXIC PROPERTIES OF COMMON VAPORS AND GASES

| Substance | Formula | Ordinary state | Boiling (1) point (deg C) | Spec. gr. of gas or vapor (air = 1) | Inflammable limits (per cent) | Physiological action | Least amount detectable by odor (ppm) | Physiological response to various concentrations (ppm): Kills in very short time | Dangerous for 1/2–1 hr exposure | Maximum concentration for exposure of 1/2–1 hr | Amounts causing slight symptoms after several hours' exposure | Maximum allowable concentration for prolonged exposure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlorine | $Cl_2$ | Gas | − 34.6 | 2.486 (1) | Non-inflamm. | Strong irritant | 3.5 (2) | 900 (3) | 14–21 (3) | 3.5 (3) | 0.35 (3) | < 0.35 (3) |
| Bromine | $Br_2$ | Liquid | 58.8 | 5.5[a] | Non-inflamm. | Strong irritant | No data | at 550 (3) | at 6–9 (3) | at 3.5 (3) | 0.3–0.45 (3) | 0.15–0.3 (3) |
| Ozone | $O_3$ | Gas | −112 | 1.62 (3) | Non-inflamm. | Strong irritant | 0.5–1.0 (3) | No data | 5 (3)[b] | No data | 0.8–1.8 (3) | < 0.8 |
| Hydrocyanic acid | HCN | Liquid | 25.2 | 0.93[a] | Non-inflamm. | Irritant<br>Asphyxiant | No data | 270 (3) | 110–135 (3) | 45–54 (3) | 18–36 (3) | < 18 (3) |
| Hydrogen chloride | HCl | Gas | − 85 | 1.2678 (1) | Non-inflamm. | Strong irritant | No data | 1250–1750 | 1000–1350 (3) | 40–90 (3) | No data | < 10 (3) |
| Hydrogen fluoride | HF | Liq. or gas | 19.4 | 0.69[a] | Non-inflamm. | Strong irritant | No data | 660 (3)[b] | 50–250 (4) | 10 (4) | 10 (3)[b] | 3 (4) |
| Sulphur dioxide | $SO_2$ | Gas | − 10 | 2.2638 (1) | Non-inflamm. | Strong irritant | 3–5 (5) | 535–650 (3) | 150–190 (3) | 50–100 (3) | 25–40 (3) | 10 (3) |
| Nitrogen tetraoxide | $NO_2$ or $N_2O_4$ | Gas | − 21.3 | 1.6–3.2[a] | Non-inflamm. | Strong irritant | No data | 320–530 (3)[c] | 117–154 (6)[c] | 105–210 (3)[c] | 50 (3)[b, c] | 39 (6)[c] |
| Ammonia | $NH_3$ | Gas | − 33.4 | 0.5963 (1) | 16–27 (7) | Strong irritant | 53 (2) | 5000–10,000 (8) | 2500–4500 (9) | 300–500 (9) | 146 (3) | 85 (3) |
| Carbon dioxide | $CO_2$ | Gas | − 78.5 | 1.5290 (1) | Non-inflamm. | Resp. stim. | No data | 50,000–67,000 (3) | 33,500–44,500 (3) | 33,500–39,000 (3) | 11,000–16,700 (3) | 5,550 (3) |
| Carbon monoxide | CO | Gas | − 19.2 | 0.9671 (1) | 12.5–74.0 (7) | Asphyxiant | No data | >4000 (8) | 1500–2000 (8) | 600–700 (8) | 500 (10) | 100 (8) |
| Hydrogen sulphide | $H_2S$ | Gas | − 59.6 | 1.190 (1) | 4.3–46.0 (7) | Asphyxiant | 0.75 (11) | 420–600 (3) | 360–500 (3) | 200–300 (8) | 100–150 (8) | 85–130 (3) |
| Arsine | $AsH_3$ | Gas | − 55 | 2.69 (1) | Inflammable | Asphyxiant | No data | 250 (3) | 15.5 (3) | 6.25 (3) | 3.1 (3) | < 3.1 |
| Phosphene | $PH_3$ | Gas | − 85 | 1.182 (1) | Inflammable | Asphyxiant | 1.4–2.8 | 400–600 (3) | 290–430 (3) | 100–190 (3) | 7 (3) | < 7 |
| Phosphorus trichloride | $PCl_3$ | Liquid | 79.95 Decomp. | 4.7[a] | Non-inflamm. | Strong irritant | | 652 (12) | 50–90 (12) | 2–4 (12) | 0.7 (3)[b] | 0.7 (12) |
| Phosphorus pentachloride | $PCl_5$ | Solid | 160–165 | Sublimes | Non-inflamm. | Strong irritant | | | Analogous to phosphorus trichloride (3), (8) | | | |
| Arsenious chloride | $AsCl_3$ | Liquid | 122 | 6.3[a] | Non-inflamm. | Strong irritant | | | Analogous to phosphorus trichloride (3), (8) | | | |
| Benzene | $C_6H_6$ | Liquid | 80.36 | 2.73 (13) | 1.4–7.0 (7) | Asphyxiant | | 19,000 (14) | 3,000 (15) | 3,130–4,700 (14) | 1,570–3,130 (14) | 100 (16) |
| Toluene | $C_6H_5$-$CH_3$ | Liquid | 111 | 3.20 (13) | 1.4–7.0 (7) | Asphyxiant | | | Analogous to benzene (3), (8) | | | |
| Xylene (*m*-xylene) | $C_6H_4$-$(CH_3)_2$ | Liquid | 136–141 | 3.68 (13) | Inflammable | Asphyxiant | | | Analogous to benzene (3), (8) | | | |
| Methanol | $CH_3OH$ | Liquid | 66 | 1.1[a] | 7.45–26.5 (17) | Anesthetic | | 290,000 (3)[b] | No data | No data | No data | No data |
| Ethanol | $C_2H_5OH$ | Liquid | 78.4 | 1.6[a] | 4–19 (7) | Anesthetic | | No data | No data | 1380–5000 (19) | No data | No data |
| Acetone | $CH_3$-$CO$-$CH_3$ | Liquid | 56.5 | 2.0[a] | 3–11 (7) | Anesthetic | | 46,000 (3)[b] | 75,000 (3)[b] | No data | 3370–4220 (3)[b] | No data |
| Formaldehyde | H-CHO | Gas | − 21 | 1.0[a] | Non-inflamm. | Irritant | | >6500 (20)[b] | No data | No data | 200 (20)[b] | No data |
| Methyl chloride | $CH_3Cl$ | Gas | − 23.7 | 1.784 (1) | 8–19 (7) | Anesthetic | No data | 150,000–300,000 (21)[b] | 20,000–40,000 (21)[b] | 7000 (21)[b] | 500 (21)[b] | < 500 |
| Ethyl chloride | $C_2H_5Cl$ | Gas or liq. | 12.2 | 2.2[a] | 4–15 (7) | Anesthetic | | 150,000–300,000 (21)[b] | 60,000–100,000 (21)[b] | 40,000 (21)[b] | 20,000 (21)[b] | < 20,000 |
| Carbon tetrachloride | $CCl_4$ | Liquid | 76 | 5.3[a] | Non-inflamm. | Anesthetic | | 10,000 (15) | 317 (22) | < 1000 (22) | No data | < 100 (22) |
| Trichloroethylene | CHCl-$CCl_2$ | Liquid | 87.1 | 4.5[a] | Non-inflamm. | Anesthetic | | 7800 (3)[b] | No data | 3700 (3)[b] | No data | No data |
| Carbon disulphide | $CS_2$ | Liquid | 46.2 | 2.6[a] | 1.50 (7) | Anesthetic | | 4,800 (3) | 3200–3850 (3) | 960–1,600 (3) | 320–390 (3) | No data |
| *n*-Amyl acetate | $CH_3$-$COO$-$C_5H_{11}$ | Liquid | 148 | 4.5[a] | Inflammable | Anesthetic | | No data | 900 (23) | No data | No data | No data |
| *n*-Butyl acetate | $CH_3$-$COO$-$C_4H_9$ | Liquid | 125 | 4.0[a] | 1.7 (7) | Anesthetic | | No data | 19,000 (3)[b] | No data | 5000 (3)[b] | No data |
| Nitrobenzene | $C_6H_5$-$NO_2$ | Liquid | 210 | 4.2[a] | Inflammable | Narcotic | | No data | No data | 1.0 (8) | 0.2–0.4 (8) | < 0.2 |
| Aniline | $C_6H_5$-$NH_2$ | Liquid | 184.4 | 3.3[a] | Inflammable | Narcotic | | >420 (24) | No data | 105–160 (8) | 7–26 (8) | < 7 |
| *m*-Toluidine | $CH_3$-$C_6H_4$-$NH_2$ | Liquid | 2031 | 3.7[a] | Inflammable | Narcotic | | No data | 540–720 (25)[b] | 91–140 (8) | 6–23 (8) | < 6 |
| Turpentine | $C_{10}H_{16}$ | Liquid | 200 | 4.7[a] | Inflammable | Irritant | | 2900 (25)[b] | 12.5 (3) | No data | 720–1100 (25) | No data |
| Phosgene | $COCl_2$ | Gas | 8.2 | 3.4[a] | Non-inflamm. | Strong irritant | 5.6 (2) | 90 (3) | 25–30 mg/l (3) | No data | 1 (2) | < 1 |
| Gasoline | $C_nH_{2n+2}$ | Liquid | 50–144 | ..... | 1.4–6.0 (7) | Anesthetic | No data | 30–40 mg/l (3) | | 10–20 mg/l (3) | 5–10 mg/l (3) | 10 mg/l (3) |

[a] Calculated.
[b] Based on animal tests.
[c] Computed as $NO_2$.


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stances. Such data have, therefore, been tabulated and are presented in Table 2. In this table are given the principal physical characteristics of various gases and vapors and the physiological response on exposure to them. The last column in the table represents the concentration of a gas or vapor which is considered safe (according to information at present available) and which should not be exceeded. Hence, given the problem of exposure to any of the substances given in the table, it devolves upon the engineer to determine methods which will keep the concentration below the given safe limit, that is, the value in the last column of the table.

### ENGINEERING METHODS OF PREVENTION

Until recently, the methods of controlling occupational disease hazards met with little attention. Since, however, the use of substances injurious to health has been associated with a subsequent rise in the number of persons affected by continuous exposure to them, the preventive aspects of the problem have seriously engaged the attention of industrial physicians and engineers. The methods which have been developed differ widely due to the varying ways in which processes and operations are conducted. Detailed information, therefore, cannot be given with respect to the design of control apparatus. In general, the control of a hazard by engineering methods can be achieved in several ways, namely: (*a*) by isolation of the hazardous process; (*b*) by exhaust ventilation; (*c*) by means of personal-protection devices, such as respirators and canister-type masks.

*Isolation Methods.* The object of this method of prevention is to segregate a particular hazard so that a minimum number of workers are exposed. Frequently, a hazardous occupation may affect workers who are not connected with it, but who work close by. An example of such a condition has been given in connection with the five workers in the foregoing chromium study who had ulcerated septa, but who were not engaged in plating operations. Isolation methods have been successfully used in plants where dust hazards exist, such as the modern sand-blast room and the hydraulic shake-out in foundries, which not only tend to localize the hazard within a definite closed area, but also expose few workers who are adequately protected by masks or helmets. Similar developments have also taken place in the spray-painting industries. Thus, spray painting and cabinets have been developed which are automatically operated and require only limited attention by the worker. The same is true of paint-drying rooms and tunnels. Isolation methods are often the simplest and most practical approach in eliminating most occupational-disease hazards. A more extensive use of these methods, however, is often limited because of the complex operations found in many plants which require frequent handling of objects and hence necessitate the exposure of a large number of workers.

*Exhaust Ventilation Methods.* The use of exhaust methods near the source of a hazard has grown rapidly in recent years. Briefly, the control of any industrial hazard by local exhaust is based on the principle that sufficient air motion must be created by a hood or opening at the source of the hazard to reduce the concentration below the threshold limit. The amount of air motion necessary cannot always be estimated directly but depends upon a careful study of the relation between the amount of air contaminant present and the airflows handled (7). Bloomfield applied this procedure with regard to the degree of ventilation required to keep chromic-acid mist below the threshold limit established by an occupational analysis previously discussed (4). The chromium-plating tanks described in the study utilized lateral exhaust. By varying the air flows handled and making determinations of the chromic-acid mist in the breathing zone of the worker, it was found that the air movement in the plane of the opening, necessary to produce a safe concentration of mist, was approximately 1500 fpm. Some variations were found when the current density in the plating process was increased, since turbulence due to gas formation at the electrodes was increased correspondingly. However, the air movement produced a safe concentration for most conditions encountered.

Since in any case the amount of ventilation required depends on the operations performed and on the shape of the hoods used, it is necessary to study each method of control separately. There are, however, some data on the characteristics of most hoods which are not obstructed in the zone of influence which may prove convenient (8). These characteristics express the conditions of air flow forward of an opening and thus allow some estimate of the performance of a particular hood. For the approximate calculation of the flow at any point along the axis of a hood without any surrounding barrier, the following formula has proved useful (8): $V = 0.1\ Q/(x^2 - 0.1\ A)$, where $V$ is the velocity of the air in fpm at a point along the axis; $x$ is inches from the opening; $Q$ is the volume of air handled in cfm; and $A$ is the area of the opening in square inches. If overhead hoods are used for lighter-than-air vapors or gases, the air velocity at the edge of the tank or basin from which they issue is given by the formula (9): $V = 0.71\ Q/PD$

Here $V$ and $Q$ are as in the former equation, while $D$ is the distance from the hood opening to the edge of the tank in feet and $P$ is the tank perimeter in the same unit. Thus, if the air movement necessary to control a given hazard at a point is known for one hood, the amount of air necessary to be handled by a hood of different size may be approximately determined.

In the case of hoods used in spray-painting operations where solvent vapors are found, it is customary, from the nature of the work, to place the object to be sprayed within the hood, while the operator stands just outside the opening. In such cases, the air flow necessary to secure safe limits of exposure is expressed in feet per minute at the opening. From studies made of the benzol hazard in various industries, it has been found that air flows of from 100 to 200 fpm are required to keep the concentration of benzol below the safe limit of 100 parts per million (10). Here again, however, data on the air movements required to control hazards caused by the use of other substances are lacking, and the investigator must devise special studies and apply the data of Table 2.

While no attempt is made in this paper to discuss the various designs of hoods in use, it is necessary to point out a few important factors in design which must be considered. First, a careful study of the operation to which a hood is to be applied must be made. A hood should be so designed that it offers a minimum amount of hindrance to the operator. Secondly, due consideration must be given to the nature of the substance to be collected. In Table 2, the principal properties of a number of gases and vapors are given. The type of hood design used, therefore, must utilize the fact that if a gas or vapor is heavier than air, it is preferable to use downward or lateral exhaust. This point has been aptly illustrated by Gumaer (11), who has shown that the tendency of a vapor such as benzol is to form into dense layers which sink gradually downward. Lighter-than-air gases or vapors, on the other hand, are best handled with vertical exhaust, taking advantage of their natural tendency to rise. The importance of utilizing the characteristics of a given gas lies not only in the fact that it simplifies the problem of control, but also it prevents any accumulation of gas in such concentrations that they may be accidentally ignited and cause explosions. For this reason there are given in Table 2 the inflammable limits of various gases

and vapors when data pertaining to them have been available. Finally, the third factor to be considered is the frequent testing and care of the ventilation apparatus. Exhaust systems should always be operated at their maximum efficiency and periodic checks should be made to see that the concentration of air contaminant is kept below the threshold limit.

*Personal Respiratory-Protection Methods.* Personal respiratory-protection apparatus are widely used, especially when isolation and mechanical methods cannot be properly designed or when workers are exposed for very brief periods of time. Such apparatus cannot be worn continuously because of the inconvenience incurred in wearing them. Consequently, they form a method of protection when other preventive measures are impracticable. Nevertheless, personal respiratory-protection apparatus form an important part in many preventive programs and a proper knowledge of their uses and limitations is extremely important.

The simplest form of respiratory-protection device is the respirator. Respirators consist of a face piece covering the nose and mouth, with a filter medium to restrain dust or mist on inhalation. A special valve is provided to facilitate expiration. Respirators are used for protection against injurious dusts, such as silica, asbestos, lead, and cadmium oxides. Their effectiveness depends upon the type of filter medium used and the manner in which it fits the wearer. A large number of respirators of various types have been developed. Many of these have been tested and reported upon by the Bureau of Mines (12). This Bureau has recently prepared a schedule of tests for respirators which attempts to standardize the procedure for determining the effectiveness of various respirators (13). Heretofore, much confusion has resulted with reference to the claims made by the various manufacturers on respirator efficiencies.

For the prevention of hazards due to exposure to gases and vapors, canister masks have been developed. These masks are made of special fabrics and cover the face completely. A flexible hose connection extends from the lower portion of the mask to a small canister containing an absorbing medium. Thus, the inhaled air is made to pass through the canister and insures pure air to the wearer. Universal canisters are supplied with a variety of absorbing materials arranged in layers and can be employed against most of the commoner gases and vapors found in industry. Canister masks, however, cannot be used where the gases or vapors are in high concentration. A range of 2 to 5 per cent of a given contaminant appears to be the maximum limit in which a canister-type mask can be used (14).

It is important to remember that canister-type masks cannot be employed in an atmosphere deficient in oxygen. Furthermore, great care should be taken to refill canisters at regular intervals to insure high absorption efficiencies.

Still another type of mask used to protect the worker is the positive-pressure mask. Such masks are supplied with a continuous flow of compressed air from a clean source. This method of protection is finding increasing use in many industries because of the high efficiencies which can be obtained. A chief fault to be found with such masks, however, is the inconvenience experienced by the wearer who is compelled to carry about with him an air-supply hose.

### MEDICAL ASPECTS OF PREVENTION

The industrial physician is in a position to estimate the success or failure of a preventive program. He is the first, by virtue of the workers who report to his clinic, to discover the characteristic symptoms of an occupational disease and to call attention to the specific occupations which are dangerous. In this connection, as has been pointed out by the American College of Surgeons (15), the periodic medical examination of workers is of immense value. Only in this way is it possible to secure and maintain the physical fitness of employees and to help increase their longevity. Workers exposed to the hazards of volatile solvents, such as benzol, carbon disulphide, etc., and to such gases as carbon monoxide and hydrogen sulphide, require medical examinations at frequent intervals to insure them against serious chronic ailments. Workers showing symptoms of poisoning should be given other jobs, and should be reexamined at later dates to determine their improvement.

### SUMMARY

This paper points out the decreased longevity of industrial workers in comparison with workers of similar social and economic status. The importance of possible exposure to occupational-disease hazards as a contributing cause in the decreased longevity is stressed, and methods of their prevention with particular reference to substances other than toxic dusts are discussed. These methods include the preliminary plant survey and occupational analysis and engineering and medical methods of prevention. The plant survey consists of a listing of all the hygienic facilities for the purpose of determining those occupations in a plant which require further study. This is followed by an occupational analysis, which is intended to show the severity of the exposure of various occupational groups and to correlate the findings with medical examinations. In this way, it is shown to be possible to determine the safe or threshold limits of exposure. The toxic limits of common industrial gases and vapors are included in table form. With regard to the engineering methods of prevention, there is discussed the comparative features of three methods in present use, namely, isolation, local exhaust, and personal respiratory protection. The value of medical supervision and periodic physical examination as a method of increasing the longevity of workers is shown to form an integral and important part in a preventive program.

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# CORRECTING OUR ECONOMY

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THE reader of economic literature, especially if he is a layman in this field, might well adopt the practice of submitting the ideas presented to him for acceptance to the two following tests: First, he should decide whether the author interprets the economic system in terms of a few or of many variables. Second, he should note the positiveness with which the writer predicts the consequences of suggested reforms. If the economic organism is depicted as simplei n design and operation, or if an infallible remedy is prescribed to cure its more serious ailments, then the reader should be on his guard. Simplification may be imperative if the ideas are to command the attention of the public; superb confidence in the efficacy of the remedial program may be necessary to secure its political acceptance; but the fact is that our economic system is an extremely complicated affair. Since it is composed of many specialized parts—persons, enterprises, and industries—its proper functioning depends on the maintenance of proper relationships between these parts. And in considering these relationships we must bear in mind that we are dealing with wilful men and women subject to changing desire, and with social institutions subject to modification by human action. The number of variable elements that are involved and their refractory character make understanding difficult and prediction hazardous.

But considerations of this kind seem to have little weight with A. G. McGregor. In his description of what he calls "the correct economy for the machine age,"[1] he boldly asserts that the way to bring about prosperity "would be for the government to decree an increase in all wages and salaries above the present level of, say, 10 per cent, then 5 per cent from time to time until all labor and capital became comfortably employed." The mere announcement of this policy, he states, will cause prices to advance in anticipation of the rise in costs and then, later, when wages and salaries begin to improve, business will benefit from increased buying by those receiving the enlarged incomes. When all labor and capital are fully employed, the purchasing power of money should be stabilized at the price level then prevailing. Tendencies for the level to fall or rise thereafter can be checked by adjustments upward or downward of amounts paid in wages and salaries. An amazingly simple method not only of restoring prosperity, but also of making it permanent!

Regarding this proposal let us ask ourselves the following questions: (1) Would the announcement of a general increase in wages and salaries cause an immediate rise of prices? (2) If so, is the raising of wages and salaries the right means of producing the desired effect? (3) Would prosperity be made permanent by keeping the value of money stable? If it can be shown that one of these three questions is to be answered in the negative, then there is reason to doubt the validity of Mr. McGregor's thesis. If it can be demonstrated that the answer is "no" to all of these questions, then wage manipulation can be definitely rejected as the master controlling device of the machine age.

As to the first question, it is difficult to give a categorical answer. It is not within the reviewer's knowledge that any government has ever made an announcement to this effect. It may be recalled, however, that the NRA when launched in the summer of 1933 was heralded with promises of higher wages; but no general rise of prices ensued. There was no apparent tendency for the receivers of wages and salaries to go into debt and increase their spending in anticipation of a future rise in earnings. The prospect of higher wages might stimulate production temporarily, but, when the new wage scale came into effect, output would probably shrink. Because of the reduction of spending for labor, materials, and other business requirements, we would be out of the frying pan into the fire. Mr. McGregor states that the bulk of consuming power is in the hands of wage and salary earners; he fails to take into account that many of these wages and salaries are earned by those engaged in making the things which the business man buys. The emphasis throughout the book is on the necessity of increased spending for consumers' goods.

Mr. McGregor writes: "In the United States, wholesale commodity prices quickly rose 25 per cent in terms of U. S. dollars in the latter part of 1922, after the raising of wages got started. Judging from this, it would seem that the mere announcement by the government that it proposed to restore higher commodity prices by bringing about a higher general wage and salary level would immediately cause a rise in commodity prices, and before the general wage and salary level had been increased as much as 10 per cent, wholesale commodity prices would probably rise 25 per cent or more." The flaw in this reasoning is that wages rose at that time because of a relative increase in the demand for labor and not as the result of a government declaration.

Of all the means which have been proposed to stimulate an advance in prices, the raising of wages and salaries by fiat of the government is one of the least defensible. Since wages and salaries enter into the cost of production of goods in different proportions, the prices of some goods would rise more than others. Shoes and textiles, for instance, would become considerably more expensive to produce, while the cost of farm products would be affected but slightly. If, as the author assumes, selling prices reflected these alterations in relative costs, farmers would be able to buy fewer shoes and textiles than before, unemployed shoe and textile workers would multiply, and the shrinkage in their purchasing power would have a depressing effect on a wide circle of other industries. An increase in the general level of prices at the present time is defensible only if it tends to restore price relationships which formerly existed. When market values declined at the beginning of the depression some fell more than others, thus creating disequilibrium between the purchasing power of producers in important industries; and a restoration of previous conditions is now advocated in the expectation that the prices which have fallen most will experience the greatest rise, and that those which have been relatively rigid in the past will remain rigid in the face of a general upward movement. In other words, a rise in the price level is envisioned as a means of reestablishing the relationships which existed in prosperous times. Mr. McGregor's plan would defeat this purpose. Those things in whose cost of production wages and salaries are a large ele-

[1] "The Correct Economy for the Machine Age," by A. G. McGregor. London, Sir Isaac Pitman & Sons. 1935. $2. (With a foreword by John A. Hobson.)

ment are not the things whose prices have fallen most during the depression. Farm products declined relatively to other goods, but in their cost of production wages are relatively minor constituents.

The product of one industry when exchanged for money is power to consume the products of other industries, and if the price-times-output of one industry is adjusted to the price-times-output of other industries, the markets will be cleared. There will be little overproduction anywhere. Giving all the workers more money to spend will not bring the various industries into adjustment with each other. By continually increasing the quantity of money, you may destroy confidence in the future value of the currency and produce a wild inflation of the prices; but this is likely to generate additional maladjustments. Nor do you guarantee that the value product of each industry will remain in balance with the value product of the others by keeping the price level stable. Relative prices may alter while the average is constant. Those who look for an economic millennium to follow the achievement of a currency unit of constant purchasing power are deluding themselves. In the years preceding 1929 prices were declining slowly and the general opinion among economists is that if changes in the price level during that period had anything to do with the depression, the source of trouble lay in the fact that prices did not decline fast enough.

Wage manipulation is presented as the correct method of regulating the economy of a machine age "to compensate for the lower cost of producing goods due to the advantages of volume production and the use of better methods." But what reason is there to suppose that technological improvements would have an equal effect on costs in all industries? On the other hand, if you raised wages most in those industries which were most successful in reducing costs, you would discourage efficiency and introduce wage differentials for the same work performed.

Mr. McGregor's book is clearly written and the author makes many intelligent and timely observations. But it is with his main thesis that we are primarily concerned. This thesis rests, in our opinion, upon a fundamental misconception of the economic process, a misconception that is the basis of many popular fallacies. In Chapter 3 we read:

The goods produced in industry have been represented as going into a pool. Capital and labor are paid in receipts (money or bank credit) for the goods they put into the pool, and their receipts are given in exchange for the goods they take out. Everything goes well as long as sufficient receipts are offered for taking out of the pool all the goods put in, regardless of how great the amount put in may be.

Most of the receipts for putting goods and services into the pool are spent in taking consumers' goods out of the pool, that is, they are spent on such things as food, clothing, household comforts, amusements, travel, etc. Other receipts for goods and services put into the pool are saved and invested in capital goods, that is, savings are invested in machinery, plant extensions, new buildings, transportation, and other facilities for the production of more goods or services, and for attaining higher efficiency in the production and distribution of goods and services.

Investment in capital goods results in more consumers' goods being put into the pool later. If too many of the receipts for goods put into the pool are saved and invested in capital goods, the quantity of consumers' goods coming into the pool will exceed the receipts available for taking consumers' goods out. Saving and investing in productive enterprises to the extent that more goods are produced than the consuming masses have buying power for must result in overproduction, unemployment, and falling prices.

The author fails to point out that investment results in the taking of producers' goods out of the pool and leads to their replacement by others, thus giving rise to receipts of an equivalent amount in the possession of investors and workers to be used for the purchase of consumers' goods. He fails to mention that these receipts placed in the hands of consumers through investment may exceed the receipts canceled through the withdrawal of producers' goods. In many instances such goods are paid for slowly by means of rents or depreciation charges representing only a percentage of the original cost. Therefore, if the volume of new investment is large, the receipts being offered by consumers may be greater than the consumers' goods in the pool available for purchase. Prices will tend to rise. If this analysis of the situation is correct, the trend of prices resulting from industrial expansion is just the opposite of that outlined by Mr. McGregor. Stability demands not a reduction of saving and investment, but such a regulation of it as will keep the amount of consumers' receipts arising from new investments in equilibrium with the amount of such receipts being canceled by current payments for past investment.

*Courtesy P.W.A.*

WELDING JOINTS IN REINFORCING STEEL IN CONCRETE PIPE FROM HETCH-HETCHY DAM

# SELLING ONE'S SERVICES

## *Third Address of a Series Before the Engineers Club of Baltimore*

By WILLIAM McCLELLAN

POTOMAC ELECTRIC POWER CO., WASHINGTON, D. C.

I SUPPOSE the first thought that will occur to all of you is that I am going to talk about getting a job. Unfortunately, this is the desperate task that faces too many engineers just now. I doubt, however, if any one can give the young or the older engineer any specific instructions on the subject, important as it is to so many individuals. For the older men with long special or general experience, and who would be valuable in many places for this reason, it is a question of finding some place where his services are needed. For the younger man with an education, but with limited experience, and especially for the young man just out of college, the problem is different in that there are many more candidates for the available jobs and these candidates have less to offer that differentiates one from another.

In all such cases, at present, my experience teaches me that one of the most important factors is personality. Those of us who are employing new men from time to time under present conditions, find that, among a relatively large number of men who have sufficient technical training for the job, the man who impresses us somehow as having superior endowments of personality, versatility, and presence is likely to get it. On rare occasions the applicant, after having studied the situation from the outside, is able to point out where he could be useful. In other words, he almost makes a job for himself that even the employer did not know existed. The lesson for the young man to learn is that, in addition to personality, persistence almost amounting to aggressiveness will land him a job sooner or later, even in times of greatest depression. The point I want to make is that, except for geniuses, success is dependent largely upon human qualities rather than technical qualifications. The young man had better learn this important lesson; and it is of equal moment to the older man, although the latter is perhaps likely to be more severely judged for the lack of these human qualities than the younger man. I propose to address myself tonight in a few words to the more general problem of selling one's services from the standpoint of succeeding in life as an engineer. In the discussion of this subject I think those who are seeking a job may perhaps find some help.

### PERSONAL CHARACTERISTICS ARE IMPORTANT

In the first place, I need do little more than refer to the necessity of paying attention to certain general features of dress, carriage, and general deportment as an important factor through life for success in any field of activity. Again I am thinking of the average individual and not of the genius who can, because of some extraordinary ability, deport himself more or less as he pleases and yet succeed. The rest of the world is willing to make sacrifices, put up with indignities, forgive omissions, and, in fact, generally adjust itself to a genius. The rest of the world, however, will not adjust itself to the great crowd of us who have no extraordinary contribution to make; and success usually comes by reason of our ability to adjust ourselves to the world. Having no magnificent outstanding personal qualities with which to impress the world, we are dependent for such impressions on much simpler things, and it is for this reason that dress, carriage deportment, and general social behavior become vital matters. It is surprising what an effect these apparently minor factors have in expressing the characteristics of a person—such characteristics as common sense, self-respect, self-confidence, and the like.

### ABILITY TO SPEAK AND WRITE WELL IS A VALUABLE ASSET

Another general factor which my experience tells me is of more than ordinary importance is the ability to express oneself in writing and in speech, particularly the latter. It is really striking how few engineers can write well. A great many are deficient even in clarity of expression, not to speak of any ability to make use of striking illustrations drawn from other more familiar fields which would help impress the reader. Too many engineering reports are deadly dull, in no way incisive; they are inconclusive, do not really demonstrate, and leave the non-technical executive or director, who perhaps must finally decide to spend or not to spend a large amount of money in a particular way, the task of digging out as best he can the answer which enables him to make his decision. More important still is the ability to express one's ideas clearly and forcibly in speech. After all, most great ideas are "put over" in oral argument. Engineers are notoriously unable to speak well, especially when on their feet I confess that this is often due to the fact that they, like men in other fields of activity have really not mastered the particular subject they are discussing, have not clearly arranged their own thoughts on the subject, and of course cannot then express themselves well. Some one has said that if a man has thoroughly mastered an idea from all angles, he will have no difficulty in discussing it. This is not the place nor is there time to give an elaborate exposition of this general subject of expression. I will say, however, that incessant practice is absolutely necessary.

The young engineer should aim to train himself better than the average in writing reports on subjects on which he has been working. Sometimes these need be hardly more than elaborate notes or summaries for his own benefit. Even though his conclusions have not been asked for, he would gain much by asking himself "What conclusions have I derived from my study?" and then attempt to express these. In order to do this well, he will be wise not to confine his reading and thinking to purely technical subjects. Wider reading in other fields will not only give him facility of expression by way of forceful illustration, but will also enable him to see his technical problems in their social setting much more clearly.

### AVOID GETTING SIDETRACKED IN DETAILS

In this connection, but more important because of its more general application, is the tremendous value of distinguishing between essentials and non-essentials. I do not know of any one thing which is more important as a factor of success than this quality. Those of you who have had any experience at all know that there are a large number of men whom we commonly call detail men; that is, men who, after any great

project has been conceived and its broad outlines finally decided upon, can work out the details. No engineer can proceed very far in a successful career whose ability is confined to working out the exact dimensions of a member of a bridge or roof truss, the diameter of a pipe, or the size of a wire to convey a certain current. Such men are too much akin to beasts of burden who will always be necessary; will be paid more or less adequately for their daily toil; but will not reap the high rewards of race-horses and other prize animals. I hope that you will understand that I am not minimizing the importance of the ultimate right decision on what might be called non-essentials, but the executive or other chief who has, to a certain extent, the future of the men in his hands, knows that these matters will be attended to. He values the assistant more and more who understands this as well as he does and can go to the essentials of a problem which are really important in controlling whatever decision has to be made, and will not, in either his written or oral discussions, spend time in discussing matters which in reality have no place in arriving at decisions.

### "FIRESIDE ENGINEERS" ARE NOT LIKELY TO GET FAR

The next factor which I would like to stress is human contacts. Some years ago, in a large organization of which I was the head, some of the younger engineers who had advanced positions in the organization came to me for a personal discussion of how they might succeed, as some of the older and more prominent engineers had done, in taking independent, advanced positions in the profession. I was compelled, in the most friendly way, to point out to them that they were "fireside engineers" which these other men, whose success in life they were almost envying, had not been. By a fireside engineer I mean a man who comes to the office in the morning, does his work, perhaps extraordinarily well, goes home in the evening to his fireside, and comes back the next morning to take up his daily grind. Such fireside engineers are, to a large extent, artizans only, no matter how technically capable they may be. They exhibit no professional spirit, which is largely expressed by the things they do outside of their daily tasks. They go to no professional-society meetings, and, if they do go occasionally, they make no effort to add to the interest of the meetings by participating in the discussion, which would also have the great effect of personal training. They serve on no committees, which would give them an opportunity to become comprehensive and broad from having contact with fellow engineers who are working at the same problems from different angles and under different conditions. They join no social clubs, which would bring them in contact with lawyers, doctors, bankers, merchants, and the like, which would broaden their ideas and enable them to understand the relation of their own technical problems to the progress of the world in general. Such contacts outside of the profession are of the greatest importance, increase one's vocabulary, and stimulate one's agility in thinking and expression.

I wish every engineer would consider seriously the responsibility he has to exhibit a genuine professional spirit, and what a vital factor it is in his success, not only in his work, but also from a pecuniary standpoint. This professional spirit will be exhibited fundamentally in a tenacious holding to the technical ideas of his profession, in his honesty of purpose, in his thoroughness of investigation, in his candid consideration of facts, and in his determination never to resort to mere expediency, which is quite different from an adequate consideration of the practical features of any situation as distinguished from the technical ones.

This, however, will not be sufficient and is not the whole of professional spirit. It must be further exhibited by a willingness to devote time and energy to the development of the profession outside of working hours and without direct pecuniary reward. As an example, long before standardization was taken up and supported by manufacturers and buyers because of its money value to them, thousands of engineers gave their time and energy to standardization as a matter of professional responsibility.

### AN ENGINEER MUST EXERCISE JUDGMENT

For fine success in the engineering or any other profession one must prove that he has judgment. This is what the world really pays for highly. It may pay well for technical ability, but the highest rewards, both in position and money, come to those who prove that they have judgment. The research worker in the laboratory can put his time on a dozen different things, but his success will come from his ability to decide among the dozen which will lead somewhere, which will accomplish something, and which are worth some time and energy expenditure. The salesman starting out in the morning has fifty prospects, but only five of them will result in a sale, and the success of that salesman depends upon his judgment in selecting that five to work on. Thousands of surgeons can actually do the mechanical work of opening and closing the body for an operation, but the great surgeon is the one who has judgment in facing conditions in connection with an operation and deciding upon the proper thing to do under some extraordinary conditions. Any engineering problem may have a number of solutions, any one of which if adopted would not result in failure, but among these solutions there is always one or perhaps two that would be much better than the others. The decision among these, again, is perhaps, first, a question of distinguishing between non-essentials and essentials, and second, in relating all sorts of social and business factors to the technical factors involved. The man who impresses his superiors with the fact that he has this kind of judgment and strengthens his ability by constant thought on this subject is going to succeed far more than the man who does not develop this quality of judgment. There is a current expression which you may have heard; namely, that technical ability is cheap, and I confess that in my long experience this is true.

I think the thoughtful person here tonight will recognize that in discussing selling one's services, I have been really discussing selling oneself. I know a large number of engineers who have done this so successfully that they never have to hunt a job. They have established themselves by their human contacts, by their exhibitions of judgment, and by their exhibition of professional spirit, so that the job seeks them. They are known from one end of the country to the other. Many organizations would be glad to get them as full-time members. They are in a position to work independently if they have the necessary additional business qualities to maintain such a position. While preserving their independence of thought and action, they have learned how to fit themselves into any organization so that the whole machine gets the full benefit of their energy.

Engineers, like other professional men, are not supposed to advertise their personal qualifications directly, but, like all other professional men, they have all kinds of opportunities as they go through life to advertise themselves. By reason of their qualities and work so that their personalities stand out, they are inevitable candidates, without immediate pressure at the time from anybody, for various positions for which they may be otherwise properly qualified. This question of selling oneself, of creating a personality, is after all the essence of selling one's services.

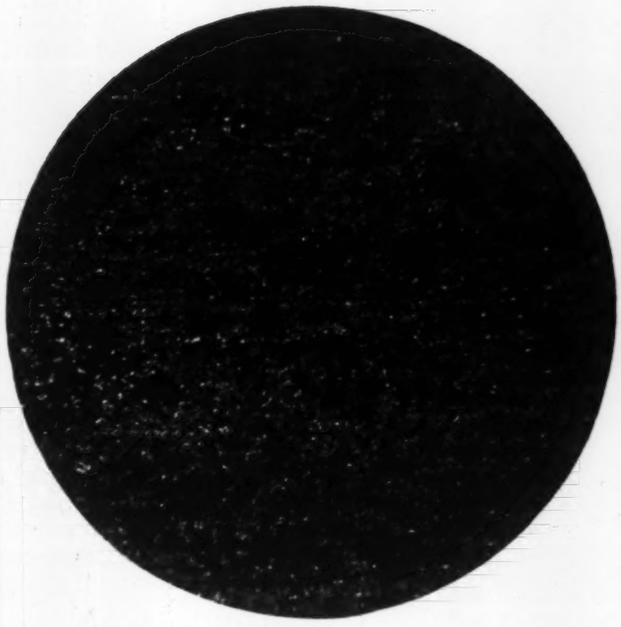


FIG. 1 CORROSION ON THE BEARING SURFACE PRODUCED BY OXIDIZED OIL DURING SERVICE (× 100)

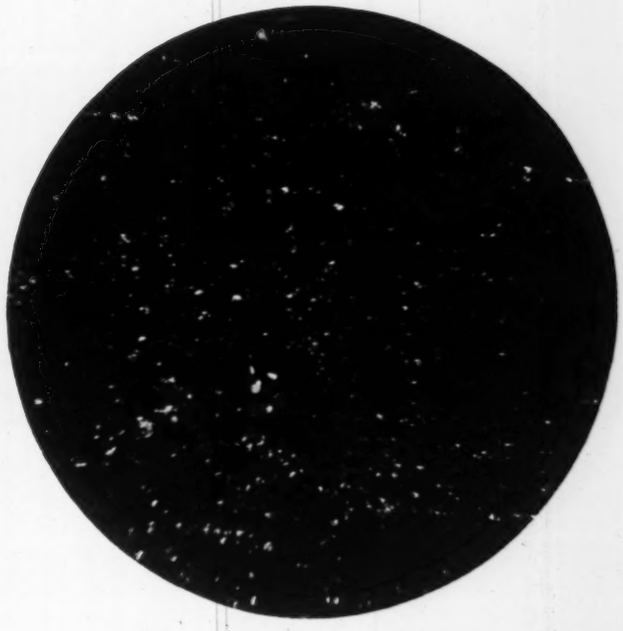


FIG. 2 SHOWING CORROSION ON THE BEARING SURFACE WAS NOT SELECTIVE, BY ETCHING WITH 10 PER CENT $HNO_3$ (× 100)

# *Corrosion of* BEARING SURFACES

By CHRISTOPHER H. BIERBAUM

LUMEN BEARING CO. BUFFALO, N. Y.

AS THE accuracy and refinements of bearing construction and operation increase, the refinements and scope for their study increase correspondingly. With the increased refinements of the mechanical and metallurgical factors entering into their construction, the physical and chemical effects in their operation now invite the fullest consideration. For it seems to have required the perfecting of all these factors to their present state in order to enable the study of the chemical or corroding effects of oxidized oils.

Some of the beneficial effects of the oxidation of lubricating oils have been fully demonstrated.[1] However, the chemical effect of such oxidized oils upon the bearing surfaces leaves a large field for further study. The oxidation of the oils has the effect of changing a chemically neutral oil to one having a distinct acid reaction, the acidity depending upon the degree of oxidation. This acidity produces two distinct effects; it changes the oil from an indifferent or non-wetting to a distinctly wetting oil, and the acidity of the oil produces a distinctly corrosive action upon the bearing surfaces.[2] These chemical reactions are exceedingly complex, in some cases the oxidized oil appears to act by catalysis only, requiring air to be mixed with the oil in order to produce a corroding action. The degree of oxidation likewise affects the capacity of an oil to emulsify with water, and in general the emulsified water has its effect of intensifying the corrosion. Oxidation and corrosion also increase with an increase of temperature, and the oil film naturally is always at the highest temperature. Therefore, all bearings in the operation of which oxidation of the oil occurs are subject in varying degrees to these corroding effects.

The amount of oxidation of an oil can be determined in a relative manner by placing a small amount of the oxidized oil on the surface of acidulated water; the water having a hydrogen-ion concentration of, say, 4 (pH 4). The oxidized molecules of the oil have an affinity for this water and thus tend to spread in a monomolecular film. This film is invisible, but by first dusting the surface of the water with fine talcum[3] or graphite, the spreading of this film or the rate of adsorption can be readily observed. The rate of spreading of a definite amount of oil gives a relative measure of the degree of oxidation.

The chemical reaction upon the bearing surface is not always uniform; in some cases it is distinctly selective and in other cases it may be a general surface corrosion. If the corrosion is

[1] "Beneficial Effect of Oxidation on Lubricating Properties of Oil," by R. O. King, Proceedings, Royal Society of London, vol. 139, no. 838 A, Feb. 1, 1933, p. 447.

[2] "Corrosion Effects of Lubricants Upon Bearing Surfaces," by Christopher H. Bierbaum, *The Iron Age*, August 31, 1933.

[3] "Constitution and Fundamental Properties of Solids and Liquids," by Irving Langmuir, Journal American Chemical Society, vol. 39, 1917, p. 1848.

selective, attacking the softer crystals only, and in a very limited degree, such a corrosion may be distinctly beneficial, for the reason that it insures an increased aggregate amount of lubricant in the oil film.[4] On the other hand, if the corrosion is a general one, attacking all crystals alike, the effect in the aggregate may be very destructive, shortening the life of the bearing despite the beneficial effect of an increased capillary affinity. Such a destructive condition always obtains in the presence of sulphur, and with many of the fatty acids, if present in only small percentages. Nevertheless, a general corrosion of all the different crystals in a bearing metal may exist and the results still prove highly satisfactory, provided such corrosion is exceedingly slight and if the resulting corroded surfaces are not inimical to retaining an oil film.

### THE CASE OF AN AUTOMOBILE BEARING

A most remarkable result was shown in the performance of crank bearings in a medium-priced, six-cylinder motor car which was brought to the author's attention. This car under unusually severe service ran 105,557 miles, without having its crank bearings adjusted or taken up, and after this remarkable performance, they were still in perfect adjustment after four and one-half years of service, at which time one of the connecting rods was removed for study. The results of this study are here given. The connecting rod was a steel forging with a thin layer of babbitt sweated upon the crank bearing surface, which originally had been tooled with exceeding accuracy, with a diamond cutter. The bearing at all times had forced lubrication at a pressure of from 20 to 22 lb per sq in. The oil used was of a pure Pennsylvania paraffin base; in its fresh state it was neutral, but after 1000 miles of service it was distinctly acid. The lubrication at all times had been given most expert and conscientious care.

The bearing was subject to a distinct though exceedingly slight corrosion due to the oxidation of the oil. Fig. 1 is a photomicrograph of the bearing surface in the condition in which it was removed, taken upon the surface in direct line of maximum thrust. It shows beyond a question that there has been no metallic contact between the surfaces at any time; that the oil film at all times supported the entire load. This latter condition is entirely in keeping with the remarkable performance of this bearing. The faint streaks or lines on the surface were caused by small particles of carbon carried in the oil. The crank surface was left in its original highly polished condition.

Fig. 2 is also a micrograph upon the same surface as that of the preceding, after it had been etched very lightly with a 10 per cent dilution of nitric acid. This shows that the corrosion in service was not a selective one, since the etching had no tendency to bring out its metallographic structure, in a manner similar to that shown in Fig. 3, which is a view upon a polished and etched metallographic surface of this layer of babbitt. Had there been no etching effect upon this bearing, its final surface condition would have been substantially that as shown in Fig. 3.

The performance of this bearing shows beyond the question of a doubt that this etched surface shown in Fig. 1 was capable of retaining an oil film. At no time during the performance of this engine under consideration was there ever a remote trace of sulphur present in the oil. The facts here shown could not have been brought out had the bearing been run to its ultimate destruction. The composition of the babbitt was tin 80.30, copper 9.43, antimony 8.58, and lead 1.69 per cent. The compression ratio of the engine was 4.9, and the bearing-load ratio was 3.17.

There are two conclusions that seem to be inevitable from the foregoing. In the first place, no matter how perfectly an engineer may construct and operate a bearing, however nearly he may attain the ideal condition of having all of the work done upon the oil film with no mechanical wear of metal upon metal, the bearing will ultimately be destroyed by the corrosion of the oil, unless oxidation of the oil can be entirely prevented. Second, destructive laboratory bearing tests are utterly futile.

[4] "A Study of Bearing Metals," by Christopher H. Bierbaum, Transactions, A.I.M.E., 1923, p. 972.

FIG. 3 POLISHED AND ETCHED METALLOGRAPHIC SURFACE OF THE BABBITT (× 100)

# *Burning of*

# CRACKED-RESIDUE FUEL OILS

By M. J. HANLON

BLACK DIAMOND STEAMSHIP CORPORATION

BECAUSE of increasing fuel-oil prices, it is necessary that those charged with responsibility for economical and efficient power generation, afloat and ashore, pay particular attention to the methods being employed in the combustion of fuel oil of any type—cracked residue, bunker "C," or high grade.

A tremendous wastage, with attendant uneconomical results, may occur through inattention to the proper functioning of oil heaters, strainers, and burners. Particular attention must also be given to the admission of air; and the quantity, velocity, and temperature of the air admitted to the furnace are important factors in securing the desired results. The pressures and temperatures maintained on the fuel oil are also of extreme importance in order that the fuel may be atomized as finely as possible with elimination of streaks and globules so that the most intimate mixture of air and fuel may be secured and the maximum combustion maintained at all times.

The quantity of air admitted to the furnace per pound of fuel oil being consumed must be closely regulated. It has been determined in marine practice that about 16 pounds of air per pound of fuel oil gives the best results, and any admission of air much in excess of this amount simply means that fuel is being wasted in heating the unnecessary air admitted to the furnace.

The burner tips or atomizers may become badly carbonized or coated with a coke-like substance caused by the burning back of the flame on to the tip. This can be easily remedied by adjusting the burner further back from the furnace.

It is also advantageous to increase air turbulence, and to permit access of additional air to the root of the flame immediately at the burner tip. Special flame cones with angular slots to produce turbulence and circumferential slots to provide flame-root air have been developed and successfully used.

It will be found that the pressures and temperatures necessary to assure proper atomization and efficient combustion will vary over a wide range and will be controlled in a large measure by the type of burner equipment and by fuel characteristics. Some types of burner equipment will require comparatively low pressures, and others will demand a much higher pressure.

No hard and fast rule can be laid down for burner and air regulation and adjustment. The problem finally will resolve itself into a process of experimentation until the best conditions are obtained. Slight changes in the adjustment of burners and air registers, as well as pressures and temperatures, will be found to produce remarkable results.

The time required on the part of the operators to arrive at a proper determination of adjustments will be justified by the results secured.

During the last few years the gasoline demand has been reflected in the fuel-oil market by a fuel type entirely different from that previously available. It made its appearance in the marine field in 1931, and immediately was responsible for considerable difficulties. Operators were not familiar with it, and the fuel was not at first uniform in its characteristics. The burning equipment with which steamers were fitted was originally designed for handling the older standard fuel known as bunker "C"—about 16 A.P.I. gravity, the specific gravity of which is 0.9593.

Presented at a meeting in New York, N. Y., Nov. 8, 1934, of the Metropolitan Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

### CRACKED-RESIDUE FUEL OILS

Although prior to 1932 the A.P.I. gravity of the then available oils dropped to about 10, it was still possible to cope successfully with this fuel without making extensive changes in the existing equipment. With the advent of this new cracked residue on the market, at an attractive price, and the general understanding that it would soon be the only fuel available, it was obvious that oil-burning equipment on steamers would have to be adapted to deal successfully with this fuel, also it was clear that a program of educating operators would have to be undertaken, and many of the older theories and practices in connection with fuel-oil burning discarded.

A few of the first difficulties experienced with this new type of oil were the plugging of heaters, strainers, and burner tips, and, not infrequently, the bursting of the strainer bodies and strainer baskets, all due to the deposition of flocculent carbon under the influence of elevated temperatures. This is one characteristic of cracked-residue fuel oils, and one of the most difficult to contend with. There is also a decided tendency to mass carbon formation in the furnace which results in flame impingement on the mass of carbon. If not attended to, this is manifested in poor combustion and the production of smoke.

The specific gravity of cracked-residue fuel oils is much greater than that of oils formerly obtainable, but the viscosity is much lower. During a period of 18 years the fuel oil available for power purposes has shown a marked increase in weight of from 7.73 lb per gal in 1916, to 8.6 and 8.8 lb per gal in 1934.

As the viscosity of the new cracked-residue fuel oils is much lower than that of the old standard bunker "C" oils, it is unnecessary to employ a temperature as great as that for the higher grade fuels to insure proper atomization. This means lower steam consumption for the heaters, which is an important item from an economy standpoint.

The atomization needed to give the best results can be secured if the oil is preheated at delivery to the burners so that the viscosity is between 3 and 5 deg Engler or, say, an average of 4 deg Engler. The corresponding Saybolt universal viscosimeter readings for 3, 5, and 4 Engler will be 105, 181, and 143 sec, respectively.

Some cracked residues have gravity characteristics of the order of 10 deg A.P.I. and a viscosity characteristic so low that they will require preheating to only 125 to 150 F in order to insure proper atomization. As a point of comparison 10 A.P.I.

gravity uncracked oil would be heated to approximately 300 F for proper atomization and efficient combustion.

In the case of uncracked fuel oils the viscosity and gravity had such an interrelation when their characteristics were expressed in degrees A.P.I. that the prediction of correct preheating could be based on the A.P.I. or Baumé gravity. This does not hold true when dealing with the cracked residues.

The cracked residues should be preheated only on the *basis of viscosity* if proper atomization is to be secured with attendant efficient combustion.

When the temperature elevation is excessive in the case of cracked-residue fuels there is a pronounced tendency to flocculent carbon deposits in all high-temperature elements of the oil-burning equipment. These carbon deposits closely resemble what is known as petroleum coke and appear in the furnace as a shower of sparks. They are discharged into the furnace through the atomizer or burner tip as solid particles of carbon or petroleum coke. If this condition exists there is a strong likelihood of forming ash particles which will eventually adhere to the furnace refractory linings and result in heavy slagging and expensive repairs.

In the combustion of uncracked fuel oils this ash apparently does not exist to any appreciable degree, or it may be absorbed in the gas stream and passed out through the stack in infinitesimal particles, although small quantities may remain in the furnace and adhere to the boiler tubes. When burning cracked-residue fuel oils a greater proportion of this ash remains in the furnace with resultant furnace slagging. A considerable quantity of ash and unconsumed carbon may also be deposited in the furnace or carried up the stack.

### ESSENTIALS FOR EFFICIENT COMBUSTION

It is essential to the efficient combustion of these cracked-residue fuel oils that the following points be closely observed:

(1) Provide correct preheating based on the viscosity of the fuel oil.

(2) Maintain a high furnace temperature.

(3) Adjust for long flame travel.

(4) Complete flame propagation in two-thirds the length of the furnace.

(5) Adjust air regulation to provide the requisite quantity by weight per pound of fuel oil being consumed.

(6) Keep excess air admitted to the furnace at a minimum as it is a waste of fuel to heat the excess air. Fuel is the sole source of heat and costs money.

(7) As an additional precaution against slagging, treat the furnace refractory linings frequently with a coating of high-temperature cement.

(8) Maintain fireside surfaces of boiler tubes in a clean condition.

(9) Guard against outside air leaks through boiler casings.

(10) Check stack temperatures.

(11) Analyze flue gases as a check against excess air, and to correct air regulation.

(12) Maintain oil preheaters, air heaters, suction strainers, discharge strainers, fuel-oil lines, burner tubes, and atomizers in a clean and efficient condition. Provide air turbulence.

(13) Do not allow furnace carbon to build up in mass formation.

(14) Do not allow flame impingement on carbon formations of furnace linings—this will result in the production of smoke and inefficient combustion.

An authority[1] on the manufacture of this fuel oil says that in treating of fuel oils having their origin in the Gulf Coast area the refinery processes consist of two major operations:

"(*a*) The crude oil is distilled or topped, yielding gasoline with minor by-products such as gas oil, and a fuel-oil residue.

"(*b*) This residue may be subsequently cracked to produce gasoline and a cracked-fuel oil residuum."

It will be observed that here are two separate and distinct operations or processes, the first of which produces a *residue* and the second produces what is termed *residuum*.

The same authority states that the method of operation of cracking processes "may be divided into two classes:"

(1) Cracking to low level or liquid residuum, and

(2) Non-residuum operation, i.e., cracking to solid residue of coke.

By using method (1) there is produced about 41 per cent gasoline, 12 per cent gas oil, and 36 per cent fuel oil. Then we are told that by using method (2) or non-residuum the gasoline yield is increased to 49 per cent, gas oil 14 per cent, and the fuel oil is reduced to 7 per cent, with a yield of about 70 pounds of coke per barrel input. The method selected for operation depends on several factors, such as gasoline price, coke price, fuel oil price, type of cracking unit used, etc.

It is further stated

that by means of the above described topping or cracking operations four different types of fuel oils may be produced as follows:

(*A*) A straight reduced crude, having a high viscosity and usually a high pour point.

(*B*) A fuel oil composed entirely of cracked residuum, having a low viscosity for a given gravity and a low pour point.

(*C*) A blend of topped crude with a high viscosity and cracked residuum with a low viscosity to give a medium-viscosity fuel oil.

(*D*) A cracked residuum run to a gravity of 10 deg A.P.I. or lower, then blended with an overhead distillate (preferably a cracked distillate) to a gravity of about 12 deg A.P.I. This results in a very low-viscosity fuel oil.

It would seem that the reduced-crude fuel oils described under (*A*) have been supplied in the past because of the extremely low market price for crude oils and limited cracking facilities available. The reduced-crude fuel oils rapidly disappear from the market as soon as the prices of crudes and consequently the price of gasoline are increased. These high prices lead to the production of a fuel oil described under (*B*), which is composed entirely of cracked residuum.

Residue or residuum at 10 deg A.P.I. are acceptable and could be satisfactorily dealt with, and at 10 deg A.P.I. would have the specific gravity of water. But some of the cracked residues have an A.P.I. gravity as low as 2.0 deg and a specific gravity of 1.06. Some of the characteristics of this fuel will be given later.

Cracked-residue fuels are excellent fuels for power purposes provided the storage tanks in power plants, or the double-bottom tanks, deep tanks, and settling tanks in steamers, as well as the fuel-oil-burning equipment afloat and ashore, are adapted for the use of this fuel.

### CHARACTERISTICS OF CRACKED-RESIDUE OILS

The cracked residues possess the following desirable characteristics:

(1) They have a low viscosity for a high specific gravity.

(2) A rapid break occurs in the viscosity of the fuel with temperature increase usually at from 130 to 155 F.

(3) The pour point varies from 0 to 15 F. This feature is most important in marine practice where extremely cold water is encountered in winter.

(4) The heating values of uncracked and cracked-residue fuel are about equal. The cracked residue is usually lower in gravity and weighs more and results in more pounds of fuel oil per gallon or barrel.

[1] R. T. Goodwin, Shell Petroleum Corporation.

The former U.S. Navy standard specifications for bunker "C" fuel have been superseded by the following:

(*A*) Navy fuel oil shall be a hydrocarbon oil, free from grit, acid, and fibrous or other foreign matter likely to clog or injure the burners or valves.

(*B*) The flash point shall not be lower than 150 F when tested in a Pensky-Martens closed tester.

(*C*) The viscosity shall be measured at two points as follows:

(1) The viscosity in Saybolt Furol seconds shall be not greater than 750 sec at 77 F

(2) The temperature at which the viscosity in Saybolt universal seconds is 150 shall be not greater than 185 F

The oil as delivered shall not contain more than 1.0 per cent of total water. For deliveries by supplier's tankers or barge, oil containing not more than 2.0 per cent of total water is acceptable with a reduction in price for all water in excess of 1.0 per cent.

NOTE: The reduction shall be (1.25 times excess water per cent) per cent of contract price.

(*D*) Ash shall not be greater than 0.12 per cent.

(*E*) The oil shall have a fire point of not less than 220 F.

If the water content of the oil prevents an accurate determination of fire point, the oil will be acceptable if the foaming due to water starts below the fire point and at a temperature not lower than 195 F. If the flash point is 175 F or higher, the fire point need not be determined.

(*F*) The oil shall be free from a tendency to deposit excessively in fuel-oil heaters when being heated for atomization at a viscosity of 150 S.S.U., for all rates of flow from at anchor to full power, with sudden changes of rate of flow and with steam to oil heater manually controlled.

(*G*) The oil shall be free from a tendency to sludge excessively in storage at temperatures from 40 F to 100 F.

In view of these specifications Table 1 will be of interest as it gives some idea of the specifications offered by certain oil refiners and on which large quantities of a cracked-residue (or residuum) fuel oil were purchased and was and is today efficiently consumed in marine practice. Particular attention is directed to the A.P.I. gravity of this fuel. The analyses given were not made by the oil refiners, but were made for the buyer by an independent laboratory of the highest standing.

TABLE 1 CONTRACT SPECIFICATIONS

| Btu per lb (17500) | Viscosity, Saybolt-Furol at 122 F 125 max | Actual Analysis: Sediment 0.25 max, per cent | Actual Analysis: B.S.&W. 1 max, per cent | Actual Analysis: Sulphur 2.0 max, per cent | Flash 150 min, F | A.P.I. 2 to 5 deg range | Pour pt. 30 max, F |
|---|---|---|---|---|---|---|---|
| 17778 | 129 | 0.63 | 0.4 | 1.05 | 202 | 2.4 | 10 |
| 17859 | 127 | 0.30 | 0.3 | 0.89 | 200 | 2.6 | 10 |
| 17753 | 117 | 0.23 | 0.6 | 0.86 | 194 | 3.2 | 15 |
| 17760 | 123 | 0.21 | 0.4 | 0.89 | 198 | 3.3 | 10 |
| 17792 | 132 | 0.24 | 0.5 | 0.94 | 204 | 3.0 | 15 |
| 17864 | 93 | 0.15 | 0.4 | 0.92 | 200 | 2.6 | 10 |
| 17804 | 102 | 0.37 | 0.5 | 0.89 | 190 | 2.7 | 10 |
| 17825 | 98 | 0.34 | 0.2 | 0.89 | 194 | 2.6 | 10 |
| 17944 | 95 | 0.24 | 0.4 | 0.90 | 200 | 3.7 | 15 |

It will be noted that the viscosity is low—very low in some of the analyses—and the specific gravity expressed in terms of A.P.I. gravity is very high.

Some figures on the specific-gravity characteristics of this fuel may also be of interest. The A.P.I. gravity range specified is from 2 to 5 deg. Now 2 A.P.I. gravity fuel oil has a specific gravity of 1.06, so that it is heavier than and will sink in fresh water. It weighs 370.8 lb per bbl of 42 U. S. gal. There are 6.041 bbl per ton.

The 5 A.P.I. gravity fuel oil has a specific gravity of 1.036, it is also heavier than fresh water. It weighs 362.6 lb per bbl of 42 U. S. gal, and a ton will contain 6.18 bbl. The heating value specified is 17,500 Btu per lb and analysis showed a better figure. The average heating value for the fuel in the 2 to 5 A.P.I. gravity range is 6,417,250 Btu per bbl, and 39,200,000 Btu per long ton.

The analysis approaching nearest to the original bunker "C" available is that of a 14 A.P.I. gravity fuel which has a specific gravity of 0.9725. It is lighter than fresh water. It weighs 340.158 lb per U. S. gal, and a ton will contain 6.496 bbl. The average heating value is 18,500 Btu per lb or 6,292,923 Btu per bbl and 41,400,000 Btu per long ton.

A third type of high-grade fuel included in this comparison has an A.P.I. gravity range of from 19 to about 27.45 deg. The specific gravity ranges from 0.940 to 0.890. For the high-grade oil at a gravity midway between 0.890 and 0.940, say, about 0.915, equal to about 23.14 A.P.I. there are 294.049 U. S. gal, or 7.001 U. S. bbl of 42 gal, per long ton. This oil weighs 319.914 lb per bbl. The heating value is 5,998,387 Btu per barrel and 42,000,000 Btu per long ton.

### COMPARISONS OF THREE OILS

A summary of the heating values of these three types of fuel oil follows:

| | |
|---|---|
| Btu content per ton of 2240 lb | |
| (1) High-grade fuel | 42,000,000 |
| (2) Approximate bunker "C" | 41,400,000 |
| (3) Cracked residue | 39,200,000 |
| Btu content per barrel of 42 U. S. gal | |
| (1) Cracked residue | 6,417,250 |
| (2) Approximate bunker "C" | 6,292,923 |
| (3) High-grade fuel | 5,998,387 |

The standard unit of purchase in fuel-oil contracts for marine purposes in the United States is the barrel of 42 U. S. gal. It is apparent, therefore, that the cracked-residue oils, due to their higher specific gravity, yield more heat units per barrel and per gallon than either the so-called bunker "C" or higher grade fuels.

In referring to atomization of fuel oils, mechanical atomization by pressure is implied.

The type of fuel preheater that has given best results with cracked-residue oils is that provided with a narrow annular space of large sectional area through which the fuel moves spirally at a low velocity. Steam at a comparatively low pressure is used for heating and the possibility of "shock heating" the fuel is obviated. When necessary this type of heater is easily opened up and cleaned.

The atomizer proper, or burner tip, should be of the type that has a high centrifugal characteristic to secure the finest possible atomization. The flame characteristic must be such that there will be no impingement on the back wall, side wall, or furnace floors. Also, the spacing of the burner units must be such that there will be no overlapping of flame-zone areas.

Preheating the air is of great assistance in successfully burning the cracked-residue oils, aside from its efficiency aspect as a means of heat recovery.

If the procedure that has been outlined is followed, and the detail changes and adjustments are made which experience in each individual power plant will indicate, the new type of cracked-residue fuel oils can be successfully and economically burned.

# ENGINEERING PROGRESS

*A Review of Attainment in Mechanical Engineering and Related Fields*

## AERONAUTICS

### Aeronautical Merger and Licensing in Great Britain

THE Wallsend firm of Swan, Hunter, and Wigham Richardson, Ltd., shipbuilders and marine engineers, have acquired an active interest in the aircraft manufacturing business of Airspeed, Ltd., of Portsmouth, and have secured the services of Anthony Fokker, the Dutch aircraft designer, in an advisory capacity. An agreement has been reached under which the British firms will acquire the license to manufacture existing types of Fokker machines and other types for which Fokker holds the license, including the American Douglas machine. (*The Engineer*, vol. 159, no. 4123, Jan. 18, 1935, p. 61)

### Rotary-Wing Aircraft

IN describing the new rotary-wing aircraft the author points out that it is not an easy thing to define the flying efficiency of a certain machine. Pure speed is an insufficient criterion, and so is paying load. It is also difficult to define an autogiro or a helicopter which would be equivalent to a given airplane. But, in general, the following conclusions can be reached.

The drag of any system of rotary wings is greater per square foot of wing than that of an airplane, but the wing area of an airplane will have to be much greater than that of a rotating-wing machine with similar top speed, unless no limitation in the landing speed is imposed. Thus, the total wing drag at top speed is about the same in principle for all machines considered.

The parasitic drag of an airplane and an autogiro need not be sufficiently different. The propulsive efficiency is the same for both. For speeds greater than some 250 mph the speed of sound will be approached by points of the rotary wings of autogiros and it is likely that some drop in efficiency will occur. As to paying loads for high-speed transport, autogiros and helicopters can be slightly superior to airplanes for short distances, equal for medium distances, and inferior for long non-stop flights. To sum up, the author believes that as far as efficiency is concerned, the helicopter is the best, followed by the airplane, the autogiro, and the paddle machine, in this order.

Next is discussed the degree of utilization of a flying machine which depends on its take-off and landing speed, on the steepness of its ascent and descent, and on its minimum horizontal speed. Here again helicopters are the best followed by paddle machines and very closely by autogiros. Airplanes are by far the worst.

It should be possible to design machines of all the four types considered, which would be perfectly stable statically. As to the dynamic stability, the autogiro with an articulated single rotor and direct control is by far the best, since it is a self-damping mechanism with stability moments very small in comparison with the moment of inertia of the machine. Airplanes can be made to be very stable at speeds above stalling, but they are decidedly unstable at slow speeds.

Helicopters with single, articulated rotors should be almost identical in behavior to autogiros, except in yawing, where it is probable that important oscillations will appear in any change of lift, due to differences in the driving torque. Paddle machines will suffer from equivalent longitudinal oscillations.

From the point of view of structural soundness helicopters are considered to be less sound than either autogiros or airplanes since they are more complex mechanically, while paddle machines must be still less sound.

In the matter of aptitude in emergency landings the autogiro shows up best, the helicopter following, after which comes the airplane. The paddle machine is considered to be a dangerous craft. (J. de la Cierva, Cambridge University Engineering and Aeronautical Society's *Journal*, 1934, pp. 13–20)

### The Kay Gyroplane

THE first Kay type-331 direct-control gyroplane has been finished at a British factory and awaits flying tests. The inventor, D. Kay, flew a rotating-wing machine in 1932. The machine performed fairly well but has been improved in design since. The latest product is an all-metal single-seater with a Pobjoy "R" motor of 75 hp, geared 0.47 to 1. It has a four-bladed air screw of wood and a four-bladed rotor with two blades forward and two backward.

The chief feature of the Kay design is the positive control of lift by variable incidence of the rotor blades while in flight. This is done by a patented rotor-hub assembly.

The design of the fuselage is of straight sections of welded-steel tube and conforms with modern aircraft practice. It has a normal tail-plane of duralumin tube with a pivoted rear spar and a movable front spar and the whole empennage, rudder and fin, may be easily removed from the last fuselage bay by taking off the fairing at the root of the fin to get at the anchorage. The leaf-spring tail-skid has a limited swiveling movement.

The tail plane has the rib formers reversed on the port side to change the airfoil section and neutralize the airscrew torque reaction at normal speeds like the ordinary autogiro.

When a system of rotors is dragged forward into wind with an angle of tilt or incidence, the rotor disk is forced by the aerodynamic lift to "cone" upward slightly, and this "cone" is determined by the centrifugal force of the revolving rotor blades. The "coning" can be kept within safe limits by increasing the rotor revolutions by varying the incidence of the rotor blades. Unhappily, this in the past had to be adjusted on the ground in the same way that the usual variable-pitch propeller of small sizes is altered. This was necessary for different loads.

At first a gyroplane had to be taxied about the aerodrome to spin the rotor; next, an extra 4 in. of travel on the elevators deflected the slipstream upward to spin the rotor; while the latest system uses directed drive from the motor. This introduced its own problems. First, torque reaction: This mattered not at all while the weight of the stationary machine rested on the ground, but when the rotor reached normal revolutions the partially air-borne machine lost stability and produced other complications. That the rotor spindle should be locked and rigid while running

up or taxying was essential, and the positive incidence of the blades made the avoidance of any appreciable angle of backward tilt important. As a precaution the locking device was on the dashboard and gave a slight forward tilt to the rotor when locked, and the machine was faced a little out of wind. The clutch between the motor and the rotor drive was disconnected at all times except when actually running up.

The Kay machine's main feature, which is the control over 8 deg of the rotor-blade incidence while in the air, entirely overcomes all these difficulties.

In the first place, when running up, a slight negative incidence is put on the rotor blades, which prevents the machine from becoming air borne, and there is an extra negative position for use in high winds which makes the machine cling to the ground.

The small incidence, either neutral or 2-deg negative, allows the rotor to be motored up to 400 rpm, which is the taking-off speed, with an expenditure of only 20 hp from the Pobjoy motor, which will reach 2800 rpm at full throttle while turning its own 4-bladed tractor airscrew and the rotor (in the low-drag position) through the 7:1 reduction.

At the moment of take-off, which can and should be made with the brakes full on, a lever on the right of the cockpit is pulled back which does three things. First it trips the clutch gear on both the dog clutch and the cone clutch, and then it puts the rotor, spinning at 400 rpm, into its positive-incidence position for normal flight. Meanwhile the Pobjoy has transferred its other 20 hp to the tractor airscrew, and by the time the rotor has slowed to 220 to 250 rpm, which is the normal speed in flight, and in so doing lifted the machine anywhere from 10 to 20 ft vertically, the tractor airscrew will have given the machine full flying speed.

In level flight the positive incidence of the rotor blades can be reduced as the air speed rises to increase the rotor speed and the consequent centrifugal force, and therefore decrease the "coning" effect on the rotor disk. The fuselage is noticeably nearly horizontal and almost parallel with the ground when at rest. The wide range of blade incidence makes a tail-down position of the fuselage unnecessary. This horizontal position is an advantage when the tractor airscrew is pulling the machine away during and after its vertical hop. Fore and aft rotor tilt is not used except in a very small degree, and this movement is inter-connected with the lateral movement of the control "weapon" (it is not a wheel or a column or a lever) to overcome the gyroscopic and turning-radius effects.

Lateral control direct on the swinging stick introduces its own problems, and when the rotor was tilted to the left the nose would be depressed by gyroscopic action, and when to the right the nose would rise strongly. Then the fact that one blade was coming forward and giving considerable lift, and the other was retiring and giving very little, would be altered in ratio on a turn by the less distance traveled by the blade which was inside on the turn. In the construction of the Kay hub has been incorporated a direct method of effecting varying ratios of positive or negative fore and aft bias (or tilt) with different degrees of lateral rotor tilt, port or starboard, so that all these effects are compounded and corrected. This is done by the "Zed"-shaped rocker spindle, which is the fore and aft gimbal mounting of the rotor mast bearing.

The fore and aft trim is set in flight by a trimming wheel or by the push-and-pull cockpit "weapon" movement on the elevators. This and the normal rudder do away with the stiffening-up at speed, which is a noticeable feature of the direct-control fore and aft tilt arrangement. At any time the machine can be flown, taken off, or landed, as a normal fixed-wing airplane.

It is claimed that the rotor with incidence control if combined with a variable-pitch propeller and a really streamlined fuselage should result in speeds as high as if not higher than those reached by the normal fixed-wing airplane of the same horsepower and weight. The Kay Company is working on a new variable-pitch airscrew using the same principle as that used at the rotor-blade roots. A complete specification of the machine is given in the original article and many details are illustrated. The general appearance of the gyroplane is a good deal like that of an autogiro. (*The Aeroplane*, vol. 47, no. 1231, Dec. 26, 1934, section on Aeronautical Engineering, pp. 772–774, illustrated)

### British Aero-Engine Industry

SEVERAL British firms, including Bristol, Napier, Rolls Royce, are engaged in the development of the compression-ignition engine. The latter's "Condor" is water-cooled and is rated to develop 500 bhp at sea level. Throughout 1934 the Bristol Company's engine department was so busy that in addition to night-shift working, 28,000 sq ft of floor area had to be added. At the same time a special lead-bronze department was established, the cadmium-plating section was extended, and enlarged hangar accommodation for the flying school was provided.

The new "Mercury" and "Pegasus" engines show an increase of about 15 per cent in power output and substantial reduction in fuel consumption. Weights have been kept down by the use of magnesium alloys. The cylinder barrels are now made of hardened alloy steel and additional fin areas have been provided to increase the cooling surface in keeping with the increased power output. Of particular interest are the steps taken to keep the exhaust valves reasonably cool. This was achieved by hollowing the stem and partially filling the cavity with a substance which was molten at operating temperature, but which had a low vapor pressure under running conditions, wetting the interior of the stem. As the valve is operated the fluid is violently agitated and heat is conducted from the base to the stem and thence to the valve guide and cylinder head. The coolant substances most successfully used are the eutectic mixture of sodium nitrate and lithium of potassium nitrate, as well as ordinary metallic sodium. Cooler valves permit an increase in power output by the raising of the detonation point.

The cylinders of the British "Salmson" engine consist of a steel barrel formed with integral cooling fins for about one-half its working length and a finned aluminum jacket cast around the upper portion and over the head of the steel barrel. Before the aluminum jacket is cast on, sheet-steel liners for the inlet and exhaust passages are attached to the steel cylinder head by welding. It is claimed that by this construction full advantage is taken of the high heat conductivity of the aluminum without bringing it into direct contact with hot gases.

The improved design of the Armstrong Siddeley engines is characterized by an increased closeness of the spacing of the external cooling fins, and a reduction in the diameter of the spark plugs with the object of increasing the surface of the combustion chamber. The same engine has a fairing ring consisting of a form of cowling designed to insure correct cylinder temperatures and at the same time to smooth out the air flow over the engine. (Details in the original article.)

A flexible drive to the airscrew shaft has been successfully developed. The sun gear of the reduction mechanism, instead of being attached rigidly to the casing as previously, is now furnished

with radial vanes, the tops of which fit into slots in the casing. The sun gear, as a consequence, is free to float in a fore-and-aft direction but is prevented from rotating except to the extent permitted by the flexibility of the vanes. A spring-loaded conical friction-damping device is provided and is permanently in engagement. As a further refinement directed toward the elimination of vibration, a flexible form of engine mounting ring has been produced. This device makes use of two rubber rings which resist the torque reaction of the engine by the shear load on them in their diametral plane.

The improvements in the Wolseley Company and the D. Napier & Son, Ltd., engines are described. Of the latter the "Dagger" and "Rapier" are both air-cooled gasoline engines, but their cylinders, instead of being arranged, as usual, radially round the crankshaft, are disposed in line along it in four banks. By this arrangement the frontal area is reduced to a figure comparable with that of a water-cooled engine. In the "Dagger" there are believed to be two crankshafts coupled to the airscrew hub through reduction gearing. The "Rapier" engine is a smaller edition of the "Dagger" and has sixteen air-cooled cylinders arranged in four lines. There are two crankshafts, one for each pair of cylinders on the port and starboard sides. Master connecting rods couple the crankshafts to the piston of the upper cylinders on the port side and the lower cylinders on the starboard side. The remaining pistons are coupled with auxiliary rods attached to lugs on the caps of the master rods.

The Napier Company make extensive use of lead-bronze bearings. (Third and last instalment of a serial article in *The Engineer*, vol. 159, no. 4123, Jan. 18, 1935, pp. 64–66)

## AIR MACHINERY

### Junkers Free-Piston Compressor

THIS development has hitherto been given little publicity notwithstanding the fact that Junkers has been working on the subject since 1912. In the free-piston compressor the crankshaft drive is replaced by an organic connection between the prime mover and air compressor producing a straight-line motion. It is claimed that several advantages are thereby secured, among others the fact that no crankshaft is needed and there are no connecting rods or additional rotating masses. There is also said to be a complete absence of vibration, as a result of which no special foundations are needed; very little floor space is occupied.

A section through a two-stage symmetrical-type construction of the free-piston compressor is given in Fig. 1 in the original article.

As a prime mover the Junkers two-stroke-cycle Diesel engine is used and each of its opposing pistons is connected to a compressor piston. There is no mechanical means of limiting the stroke of the latter and the compressor pistons are permitted to move freely outward on the working stroke of the two-stroke Diesel engine. In doing this they compress to the desired pressure the air contained in the compressor cylinders. When the pistons have given up their energy they come to a standstill. The return of the two pistons and hence the compression of the air in the working cylinder of the Diesel engine take place through the energy given up by the air which is at that time under the compression corresponding to the delivery pressure in the clearance space of the compressor cylinder and this continues until the air expands down to suction pressure. As soon as this has happened the compressor pistons for the rest of the inward stroke suck the air in, whereupon the cycle is repeated.

The simultaneous operation of the two pistons is insured by a drive coupling consisting of two racks meshing in pairs with two gear wheels located in the middle of the machine. The fuel pump and the other accessories of the Diesel engine are driven from the shaft of these gear wheels.

In accordance with the delivery pressure desired the governor regulates the output of the motor by controlling the amount of fuel delivered to it by the fuel pump. At partial load, which means at reduced air delivery, the machine operates with shorter piston strokes. At full load it has the maximum piston stroke and at no load the minimum. The Diesel engine located between the two compressors operates in the conventional manner, the opposed pistons controlling the scavenging and exhaust ports.

The cylinders of the air compressor are equipped with automatic spring-loaded plate valves. The pressure-control valve is located behind the last stage. Careful provision has been made for cooling the apparatus. In multi-stage air compressors the air delivered from each stage is cooled in intermediary coolers and dried at the same time. For use where space is at a premium a simplified design has been worked out.

Because of the working cycle selected and construction adopted it is said that the compressor weighs only very little. It is claimed that the free-piston compressor is of particular advantage in places were light weight, small floor space, and easy installation are of importance. In its present state of development this type of compressor can be used for pressures from 3 to 250 atm abs. It has been used, for example, as a stationary industrial compressor giving in two stages compressed air at 7 to 9 atm gage, or, in three stages, an operating gage pressure of from 30 to 60 atm, these being used for charging compressed-air containers.

The four-stage design can be used for generation of compressed air for high-pressure air bottles, where operating gage pressures of 150 to 250 atm are required. It is also said to be suitable for use on shipboard and for delivering air under pressure for starting Diesel engines.

By a clever arrangement of individual stages the machine is completely symmetrical and made of short length. This two-stage symmetrical construction is shown in Fig. 1 in the original article as having on each side a working cylinder of a tandem compressor. Fig. 3 of the original article shows the high-pressure compressor taking in 120 cu m of free air per hour and compressing it to 205 atm gage with a fuel consumption of 9 kg.

Because of the fact that crankshaft drive and other rotating masses are here eliminated and the compressor and the prime mover connected in such a manner as to insure a straight-line motion, the dynamics of the free-piston compressor differ from those of a compressor driven through a crankshaft. The forces necessary for moving the masses and for compressing the air are supplied on the outward stroke of the compressor by the power stroke of the Diesel engine. Since the energy necessary for the return stroke is taken from the air contained in the clearance space of the compressor where at that time a proper air pressure prevails, the clearance spaces in each stage of the compressor must be so proportioned that the amount of energy available should be sufficient to provide the energy required during the return stroke. Because of the fact that the length of the stroke is controlled at part load, a certain change in the energy consumption during the return stroke must be taken into consideration as it affects the compression end pressure that may be attained. This pressure must be of a predetermined magnitude at all loads in order to insure a certainty of ignition of the motor fuel.

The author develops a series of equations expressing the working processes of the free-piston compressor and providing ways to determine the dimensions of the parts. This part of the article, mathematical though elementary, cannot be abstracted because of lack of space.

It is claimed that this compressor is easy to start and runs smoothly. Moreover, with the elimination of crankshaft bearings, pressures may be used which could not be employed otherwise. (Kurt Neumann, Communication from the Institute of Internal Combustion Engineering and Technical Thermodynamics of the Technical High School in Hannover, abstracted from the *Zeitschrift des Vereines deutscher Ingenieure*, vol. 79, no. 6, Feb. 9, 1935, pp. 155–160, 8 figs.)

## ENGINEERING MATERIALS

### Mechanical Treatment of Electrodeposited Coatings

WHEN parts built up by electrodeposition were first made available every effort was made to supply as hard and tenacious a deposit as possible and little regard was paid to the subsequent machining. Today both machines and tools employed are carefully selected to insure that any one particular deposit will be most rapidly and accurately handled. Every care must be given to the actual hardness of the part to be machined as it does not follow that all sections will be equally hard; this all the more so where the built-up parts are widely different in shape. The reason is that the throwing power of the current is apt to be impaired by the different positions which the sections occupy in the depositing vat. It is recommended that parts be tested for hardness before proceeding to mill or turn the section. Hardness, however, does not necessarily indicate the ability of the deposit to resist wear and some better system of testing is desirable. Tests to destruction followed by ordinary photographs (not photomicrographs) are considered to be of great value as in this way the nature of the adhesion can be approximately determined.

Nickel, chrome, and iron deposits can all be machined in the dry condition and the use of a lubricant is only necessary to preserve the cutting edge of the tool. Where possible it is generally advisable to remove the surplus deposit by grinding methods as opposed to turning or milling. An exception exists in the case of certain iron deposits as these can be carburized and converted to any desired hardness to suit the cutting tool. Some practical advice as to grinding methods and machining by tantalum-carbide or tungsten-tipped tools are given in the original article. (*Engineering*, vol. 139, no. 3602, Jan. 25, 1935, p. 101)

### Refractories for Gas Retorts

CARBONIZERS, whether on coke ovens or gas retorts, are continually making increased demands upon their refractories. Higher temperatures, more rapid carbonization, and discharging to schedule have all been responsible for the need of improvement in refractories. This has resulted in the general use of silica brick for the setting and for the walls of coke ovens, and their employment has brought with it a number of problems.

The Institution of Gas Engineers in its new standard specifications for refractories refrains from specifying "refractoriness-under-load" in figures and by a standard test. The reason for this omission lies in the difficulty of prescribing a test which will be capable of giving unquestionable results. The problem has been since tackled by the Refractory Materials Joint Subcommittee of the Institution of Gas Engineers, the Society of British Gas Industries, and the British Refractories Research Association. The recently published report of this body contains a review dealing with this test.

Preference is expressed for a test providing a continuous temperature-deformation curve. On the other hand, it was found experimentally that with a test of this character, if proper allowance is not made for the expansion of the supports and thrust blocks of the furnace, an error of as much as 300 C is possible in the apparent temperature of deformation. No recommendations can yet be given upon the size of the test piece, but it has been established that there is a close parallel between the dimensions of the specimen and the temperature gradient.

Considerable information has been obtained through a questionnaire submitted to the gas concerns who are members of the British Refractories Research Association. This has shown a wide difference in the working life of refractories. The reasons for and implications of this are discussed in the original article. The causes of damage in horizontal and vertical retorts are enumerated. Among other things, the report deals with an investigation which was undertaken into the manufacture of an insulating brick capable of being used at high temperatures, above those around 900 C up to which existing insulators can be used. Crushed ganister suitably bonded and mixed with sawdust or powdered coke has given encouraging results with a high refractoriness-under-load, and in an attempt to increase the porosity carefully graded mixtures of coke and ganister have been used and appear to be highly promising. (Editorial in *Engineering*, vol. 139, no. 3599, Jan. 4, 1935, pp. 15–16)

### Developments in the Rolling of Sheets and Strip, 1934

AFTER giving a brief history of broad strip mills, the author tells of the latest developments. The part abstracted here deals with sizes of product.

Work is under way for remodeling the 28-in. wide strip mill at the Gary plant of the Illinois Steel Works, and a further remodeling of the 96-in. continuous plate mill at the South Chicago Works of the same company is under consideration. In the former case the present two-high finished stands are to be replaced by a similar number of four-high stands, permitting the production of wider and thinner strip. In the latter case an additional stand of four-high rolls is contemplated to enable the mill to produce comparatively light-gage strip, 12 gage and under, in widths up to 90 in., and in coils.

The Ford Motor Co. will have facilities for producing strip in gages as light as No. 18 up to 48 in. wide.

The Youngstown Sheet & Tube Co. will install a continuous strip mill at the Campbell plant designed to produce light plates and skelp from $1/4$ to $1/2$ in. in thickness and hot-rolled blue-annealed sheets, 12 gage and heavier, up to 72 in. in width.

The Carnegie Steel Co. at McDonald, Ohio, has placed an order for a mill of ten stands of horizontal rolls two high and four high, two vertical edgers, and two horizontal scale breakers. The mill is designed to roll 16-gage strip up to 38 in. wide and 18 gage to 24 in. wide.

Two hot mills of the Steckel type are under construction and one is being rebuilt. One will be set up in tandem with a 42-in. two-high universal mill, in which the slab will be broken down to plate thickness before passing it to the Steckel mill. The other two mills will be of the single-stand type in which all the work from the slab to the finished mill will be accomplished in a single stand of rolls.

Of the cold-rolled mills, two 42 in. wide have been installed by the Gary Tin Mills and two 84 in. wide at the Gary Sheet Mills. The Eastern Rolling Mill Co. at Baltimore, Md., has now a four-high cold mill with rolls, 16 in.–44

in. by 84 in., for cold-rolling sheets in short lengths, particularly to meet demands of the automotive industry for full-finished auto-body sheets. The Ford Motor Company's cold-strip mill will be used for the production of full-finished sheets in widths up to 84 in. in various gages. The cold-strip mill of the Youngstown Sheet & Tube Co. will be capable of producing full finished auto-body sheets as well as less highly finished grades of cold-rolled sheets up to 69 in. in width and on single-stand without reel up to 84 in. in width.

The author states that the great problem that is still left with the future for solution is that of producing sheets or strip in auto-body gages up to somewhere in the vicinity of 100 in. wide. Whether this will be done in a long strip by means of rolls of that length and corresponding motor horsepower or whether a narrower strip will be rolled to be later spread to the desired width is something that the industry does not know. (Stephan Badlam, Cons. Engr., Pittsburgh, Pa., paper presented at the Annual Convention of the American Iron and Steel Electrical Engineers, Cleveland, Ohio, Sept. 18–20, 1934, abstracted through *Iron and Steel Engineer*, vol. 11, no. 12, December, 1934, pp. 500–510, 4 figs.)

### Physical Properties of Metals at Low Temperatures

WHILE the title refers to engineering materials generally, only the behavior of metals is actually discussed. This behavior at low temperatures is characterized by the observation that with decrease of temperature the resistance to changes of shape increases and simultaneously increases the ratio of resistance to change of shape to resistance to rupture. It would appear, therefore, that the static rupture test shows generally an increase both in the final strength and in the elastic limit.

This matter was extensively investigated, in particular by Rudeloff, Goerens, Mailänder, Pester, Gruschka, Sauerwald, and their collaborators. The Gruschka tests on steel show that for every degree of fall of temperature there is an increase in physical strength of from 0.1 to 0.3 per cent. This regular increase in strength at low temperatures was also found in other metals, but the behavior as to elongation in the case of aluminum alloys and soft copper, as more fully discussed elsewhere, differs from that of steel.

In discussing the notch strength of materials the author starts with carbon steel and points out that when such steel is subjected to heavy stresses causing material deformations, the resistance to rupture is predominant, particularly where notch effects are also present. If the resistance to change of shape becomes greater than the resistance to rupture, so that a complete or partial rupture takes place first, both the ability to undergo deformations and the work of rupture fall off greatly and the material becomes porous. All carbon steels show this porosity at very low temperatures. In notch shock tests this continues until the notch strength reaches very small values, as shown in Fig. 1 in the original article. In this case the composition and structure of the material have a decisive influence. If the strength of the steel is increased by raising its carbon content, the porosity-producing effect of the low temperatures increases.

Of particular importance as determining factors of the behavior of steel are its grain structure and method of rolling. Steels of the same composition but differently rolled may show different behavior, as is illustrated by curves in the original article. The porosity due to low temperatures increases greatly in the case of a material that has been cold-worked and then for a long time maintained at room temperature, or for a short time at temperatures of from 150 to 200 C. A set of curves in the original article shows this aging of a sample of silicon structural steel with a tensile strength of 54 kg per sq mm. As this example shows, the cryogenetic porosity of carbon steel may often appear at room temperature or at moderately low temperature if a strong notch effect is present. If less of the notch effect is present the danger range moves down to deeper temperature, but if the temperature is sufficiently low, which for carbon steel means from 155 to 180 C, even smooth test pieces free from notches show an extensive porosity and break easily, practically without any contraction of area.

On the other hand, the cryogenetic porosity may be greatly reduced by the use of heat-treated alloy steels, particularly the group of pure nickel steels or such steels alloyed with other materials. Here again the matter of structure plays an important part and an effort must be made to obtain as evenly sorbitic a structure as possible.

Chromium or chrome-molybdenum steels extensively used in the United States in motor-vehicle construction make it possible to secure with careful treatment a much lower degree of cryogenetic porosity than carbon steel. In this case, even more than in pure nickel steels, the behavior of the material depends on the structure thereof and on proper heat-treatment. At very low temperatures for metal of the same composition, thick blocks show less satisfactory notch strength than rods when tested in the direction of rolling.

In order to obtain a fully satisfactory sorbitic structure and hence high tensile at low temperatures, thick blocks require a higher content of alloy additions, particularly nickel, as well as exceptionally careful metallurgical refining and heat treatment. This is illustrated by the following experience: The steel commonly used for gun manufacture before the World War contained either from 5 to 7 per cent nickel or from 3 to 4 per cent nickel and about 1.5 chromium. This steel when properly manufactured gave a very high bursting resistance in the case of an explosion of a shell in the gun tube. By improvements in heat-treatment and methods of manufacture the German mills succeeded during the War in obtaining the desired bursting strength with a very much reduced nickel content or even no nickel in steels of sorbitic structure. In every case, however, it was found that there was much difficulty in obtaining the same bursting strength in winter in low-nickel steels.

It would appear, therefore, that in the case of machinery which might be subjected to great stresses at very low temperatures, it is necessary to be particularly careful about avoiding notch effects. If this cannot be done, only materials treated so as to produce an irreproachable sorbitic structure will give sufficient low-temperature strength when used in larger cross-sections. This can be done above all with steels of the nickel or nickel-chromium group, providing the content of nickel is sufficient to give satisfactory performance for the stresses expected and the cross-section that must be employed.

Of the known metals, zinc shows a pronounced cryogenetic porosity greater even than carbon steel. On the other hand, copper and aluminum show no dangerous tendency toward rupture even at the lowest temperatures and very strong notch effect. In the case of hardened aluminum alloys, such as duralumin and lautal, there is no particular inherent danger of rupture, but at very low temperatures there is a notable decrease in capacity of deformation, so that while the work of rupture at very low temperatures does not decrease, it does not increase either.

As regards strength in long-duration loadings at low temperatures affecting the permissible alternating stresses in machine parts, no reliable tests have been published. This led the author jointly

with E. Dorgerloh, of the Institute of Metallurgy and Technology of Materials at the Technical High School in Dresden, to investigate the alternating stress with bending at temperatures down to —40 C. This was done on the following materials: Copper, soft annealed and hard; aldrey, hardened and hard drawn; bondur and duralumin, hardened. The non-ferrous metals were available in rods 5 mm in diameter, longitudinally polished and tested without further treatment. The details of the tests are set forth in the original article and the results presented in the form of two tables and curves.

These tests have shown that in all materials, with the exception of hard-drawn pure aluminum, the tensile strength increased with the decrease of temperature and was most pronounced in the case of steel and least in the case of hardened light metals. The increase in elastic limit for carbon steel S-t-34 (a standard German steel) was even greater than the increase in tensile strength, while for all other materials it was smaller. In the case of soft copper and to some extent that of light metals a decrease of the elastic limit was noted and was found to be largest in the case of soft copper.

The materials did not behave in the same way in reference to strength in alternate bending. The two steels tested showed a strong increase in alternate bending strength which in the case of smooth bars was more than twice in percentage the increase in tensile strength and elastic limit. The behavior of notched bars was particularly notable. In the case of very soft S-t-34 carbon steel the notch alternating bending strength increased amazingly down to —40 C, and in the case of steel S-t-C-60.61 at —25 C, it was still materially greater than the alternating strength of smooth bars. At —40 C the notch alternating bending strength of the high carbon steel S-t-C-60.61 falls off, but at all times remains higher than similar strength at room temperature. This may have been assisted by the lower "notch viscosity" of that steel, but this alone does not explain the phenomenon completely, as steel S-t-34 showed at lower temperatures a much steeper falling off in notch viscosity in the region of rupture than high carbon S-t-C-60.61.

In all other materials where only smooth bars were used for tests a lower increase in alternating bending strength was found. The relative behavior of the various materials as compared with each other is substantially similar to that found in tensile rupture tests. The actual figures are given in the original article.

The following conclusions are claimed to be of particular interest: In the case of steel the tensile strength, elastic limit, and alternating bending strength increased materially, the last one nearly twice as much as the tensile strength. This holds good down to at least —40 C not only for smooth but also for notched bars. Copper showed similar percentage variation in the alternate bending strength of smooth bars as used. The behavior of the elastic limit, however, in the case of very soft annealed copper differed from this and forms a subject which needs further investigation. In the case of light metals, particularly hardened alloys of aluminum and aldrey, the change in physical properties, particularly the alternating bending strength of smooth bars down to —40 C, is small and, in general, may be neglected. Therefore, if stresses on parts of structures are set in accordance with those found to be right for room temperature, at low temperatures an added factor of safety will be present in the case of steel, while in the case of light metals the same factor as at room temperature will be available. Where very great stresses have to be considered the material decrease in "notch viscosity" of carbon steels at low temperatures must be taken into consideration. This means that particular care should be exercised to avoid all notch effects and sharp changes of cross-section. (W. Schwinning in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 79, no. 2, Jan. 12, 1935, pp. 35–40, 18 figs.)

## FUELS AND FIRING

### Spontaneous Oxidation of Coal

THE oxidation process in coal was studied in some detail at the Doncaster Coal-Owners' Laboratory. At a constant ordinary temperature it was found that with pulverized coal oxidation was comparatively rapid at first, but quickly diminished until it became almost inappreciable after several days, and it was only a very small proportion of the coal which had oxidized. With coal in lumps, however, the oxidation was far slower and continued for a much greater time. With a large lump of coal the oxidation took many years to penetrate into the center of the lump. Coal which has broken up, or is not freed from small particles by cleaning, is thus much more liable to heating unless access of oxygen is in some way prevented.

As regards the oxidation of ordinary air-dried coal the volume of carbon dioxide found was only about one-fifth and the heat produced by the oxidation was found to be only about one-half that produced when the same volume of oxygen was used up in the complete combustion of coal. Thus the oxidation process in dry coal at ordinary temperatures is incomplete in its character, as well as very limited in amount, though on raising the temperature it becomes more extensive. Different varieties of coal, when pulverized, vary considerably in regard to the amount of oxygen which they consume at ordinary temperatures, and this fact, and still more their relative friability, helps to determine their relative liability to spontaneous combustion.

In 1933 the authors described a series of experiments which threw light on this subject. Knowing that moistening of both hay and coal markedly accelerates the rate of chemical oxidation, the authors made a number of observations in which the results of oxidation in air-dried and in wet coal were compared. In these experiments, coarsely ground coal of known weight and one variety was used, and they selected coal which had been exposed sufficiently long to air to insure that any absorbed methane should be small in amount. The coal was placed in equal amounts in equal closed flasks, each connected for convenience of observation to a mercury pressure gage, and placed in a water bath kept at a fixed temperature. The following pair of similar experiments illustrates the influence of moisture. In the first with the dry coal dust at 40 deg the oxygen was not wholly absorbed until the seventeenth day, when the residual gas contained 4.26 per cent of carbon dioxide, 0.32 per cent of carbon monoxide, and 0.18 per cent of methane. In the second, again at 40 deg, the dust was well damped with water. The oxygen was not absorbed by the ninth day, and the residual gas contained 7.67 per cent of carbon dioxide, 0.11 per cent of methane, but no carbon monoxide, although a small amount had been present at an earlier stage of the experiment. (Paper before the Society of Chemistry & Industry, by J. S. Haldane and R. H. Mackgill, abstracted through *The Steam Engineer*, vol. 4, no. 5, February, 1935, p. 184)

### Coal Cleaned by Gravity

CERTAIN recent developments have been directed toward improving the flexibility of coal washing plants and the fluidity of material and dirt beds in jigs. A raw-coal bunker of ample capacity is desirable at a washery so that minor

repairs will not interfere with the working of the colliery. The usual arrangement has the bunker in series with the washer box.

Lately V. H. Adams has suggested having the bunker in parallel so as to avoid degradation of the coal, due to the fact that in a series connection the bunker, to be useful in case of breakdowns at the washery, must be kept fairly empty. In the Adams arrangement the full capacity of the bunker would be available as a safeguard. The raw-coal bunker would be normally kept empty and the feed from the screens by-passed and taken to the washer. Should repairs be necessary the coal may be fed in the usual manner.

The parallel arrangement of the raw-coal bunker makes it necessary for the washing box to deal with considerable variations in the rate of feed. In the modified Baum washer box the strength of the pulsations is automatically regulated according to the requirements of the feed. In jigging there are at least two beds to be considered, an upper jigging bed of light material and a lower dirt bed of heavy stuff. The matter of pulsations control becomes important. Baum developed a self-regulating jig. The device so far has been tested only on the model washer at Birmingham, England, and in one test with $^1/_8$-in.-0 coal the 1.50 floats in the dirt were reduced from the average of 7 to 3 per cent.

The modification has a wider application to pneumatic than wet jigging. An experimental pneumatic jig, somewhat resembling the Slater air jig but in which the feed was introduced in the normal way, was modified by using ribs laid over the sieve plate. The modification cured a troublesome tendency of the dirt bed to segregate in particular areas, thus facilitating the discharge of dirt. A brief reference is made to the Hirst patent stirrer, comprising a horizontal grate, provided with downward projecting prongs, which is suspended above the jigging bed and reciprocates transversely by duplicate eccentrics and cranks The clearance between the sieve plates and the extremeties of the prongs can be varied by raising or lowering the grate. It is said that the stirrer gently agitates the jigging bed, thereby reducing contact forces and speeding up the process of separation and that its installation has been found to increase the efficiency of washing under conditions of overloading. (Arthur A. Hirst, Coal Treatment Research Laboratory, Birmingham University, in *Mechanical World*, vol. 96, no. 2498, Nov. 16, 1934, pp. 474–475)

## INTERNAL-COMBUSTION ENGINEERING

### Diesel Industry in the Depression

WHILE other capital-goods industries are striving to find a way to start their wheels turning, the Diesel industry has definitely surmounted the depression, in fact is on the way to prosperity.

As Fig. 1 reveals, sales up to November 1, 1934, were almost 50 per cent higher than for the best previous year, 1928. It is not unreasonable to expect the total to reach 700,000 by December 31, and sales for 1935, to soar to 1,000,000 hp.

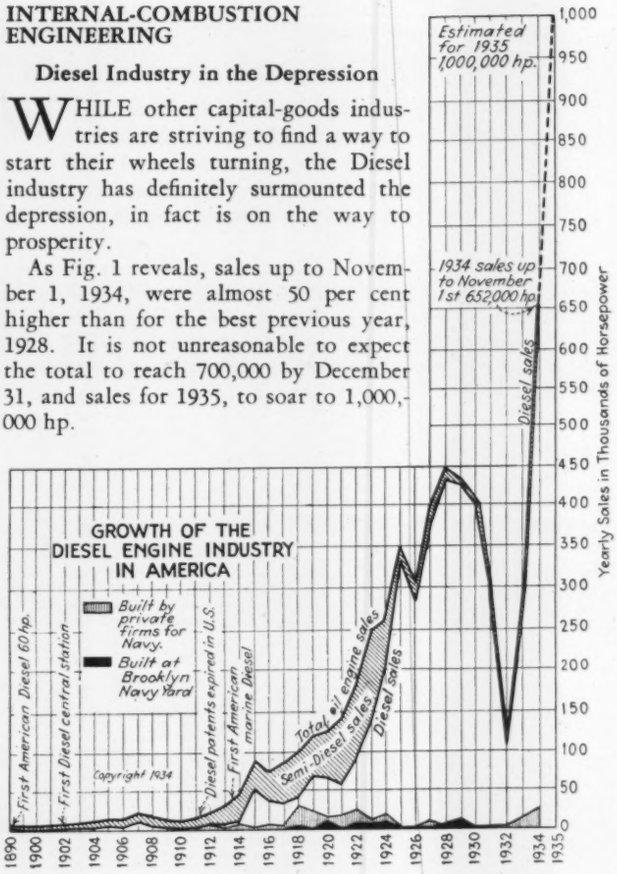



FIG. 1 GROWTH OF THE DIESEL-ENGINE INDUSTRY IN AMERICA

Much of the increase is traceable to new design, new manufacturing methods, and a more diversified application of Diesel engines. (*Diesel Power*, vol. 12, no. 12, December, 1934, p. 671, 1 fig.)

### The Future of the Coal-Dust Motor

THIS is part of an address delivered at the technical meeting of the Association of Mining Interests in Essen, October 18, 1934, and is based on tests carried out by Pawlikowski, the Schichau shipyards, the first Brünner Manufacturing Co., and an extensive report prepared by Wahl on the tests carried out for the Associated Interests for the Dye Industry at the Oppau plant. As the subject has been already extensively referred to in MECHANICAL ENGINEERING only those parts which appear to be new are here abstracted.

Tests have indicated that the theoretical demand for air in the case of lignite coals is from 5 to 6 cu m per kg, for bituminous-coal dust 7 to 8 cu m, and for gas oil 10.3 cu m.

When properly compared, all the three fuels give approximately the same output, as has been established by tests. The excess of air in the Oppau tests was of the order of 60 per cent. The end pressure should not be excessively high as this increases the weight of the machine and particularly the wear. A table in the original article is given containing ignition temperatures of various solid and fluid materials in air at atmospheric pressure but without regard to the duration required for ignition. The data are given for fuel at rest and for coal dust floating in the air.

The process of ignition of coal dust in a bomb has been investigated by Wentzel but further information is necessary, particularly as the figures obtained in bomb tests cannot be directly applied to engine operation, because the injection and turbulence of a fuel-dust-air mixture in an engine create far more favorable conditions for the ignition and combustion than exist in a bomb. The experimental Diesel at Oppau permitted the use of lignite dust, cold, with an end pressure of 25 to 30 kg per sq cm. As these tests were carried out with fat coal dust, one may figure on an end pressure of 25 kg per sq m when gas and gas-flame coal is used. Tests have shown that the handling of poorly ignitible coals can be assisted by an admixture of easily ignitible coals or oil. However, since this complicates the operation, it becomes necessary to select the fuel in such a manner that it would be suitable for use in a motor with the lowest possible end temperature and a low end pressure.

In 1932 Schor investigated the pressure and temperature conditions in a cylinder and has shown that they are approximately the same with dust as with oil, so that thermodynamically there is no difference between the operation with the two fuels. Because of this, the theoretical thermal efficiency and the theoretical consumption of fuel are the same with coal dust as with oil. The actual thermal efficiency, however, is 25 to 31

per cent with a coal-dust motor and 30 to 34 per cent with an oil-fired Diesel, a difference which will probably be reduced with the further development of the coal-dust motor.

At Oppau, diagrams were obtained with an indicated average pressure up to 11 kg per sq cm. Pawlikowski claims that average pressures similarly indicated were 11.45 kg per sq cm while the Brünner Company obtained pressures of only 5 to 6 kg per sq cm. These low pressures could have been obtained only with comparatively tight pistons as the wear of the packing elements reduces the average indicated pressure by 1 kg and more per sq cm.

The heat consumption per unit of indicated output in the Oppau tests amounted to 1500 kcal per ihp-hr, with an average indicated pressure of both 4 and 9 kg per sq cm. These values rapidly increase with increasing wear of the packing elements. The average fuel load per unit of volume of cylinder content of a coal-dust motor amounted, according to the Oppau tests, to about 50,000,000 kcal per cu m per hr, while the peak loads during the short period of combustion in a four-stroke-cycle motor run up to about 1,000,000,000 kcal per cu m per hr.

The parts dealing with the design of the motor valves and precombustion are not abstracted because they have been described elsewhere. According to the Oppau tests the consumption of injection air with coal dust ran to about 1250 liters per min as against 350 liters per min with oil as fuel. Zinner has recently published a short account (*Zeitschrift des Vereines deutscher Ingenieure*, Vol. 78, 1934, p. 1007) of tests on the measurement of fuel and its air injection into the cylinder as carried out in the machine laboratory in Dresden by Professor Nägel. It was found that variations in the fuel supply of from 3 to 5 per cent either plus or minus are unavoidable in a coal-dust motor and that the variation in the speed of rotation produced thereby has to be taken care of by the flywheel. In the Oppau tests the mechanical efficiency of a 450-hp engine was about 61 per cent with coal dust, and 75 per cent with oil. Pawlikowski gives for a three-cylinder engine the mechanical efficiency as 65 per cent and the Brünner Machine Works as 68 to 70 per cent. This low mechanical efficiency of the coal-dust motor as compared with the oil-fired Diesel is due to the higher frictional work and the cost of injection air. In a coal-dust motor having no scavenging air the mechanical efficiency could be raised to about 70 per cent.

In accordance with the mechanical efficiency of the Oppau engine the heat consumption, when referred to actual output, gave 2500 kcal per effective hp-hr. The speed of rotation is naturally limited by the duration of the time necessary for igniting the coal dust. In the Brünner tests it amounted to 167 rpm and at Oppau to 215 rpm. While these slow running motors are satisfactory for stationary plants, for motor vehicles high-speed machines are required. It should be mentioned further that the starting period of a coal-dust motor from dead to full load requires less than one minute and that the machine can be operated even by unskilled labor.

The article discusses next the wear on coal-dust motors and the kind of fuel that can be used therein. (First instalment of a serial article by Fr. Schulte and W. Litterscheidt in *Glückauf*, vol. 70, no. 50, Dec. 15, 1934, pp. 1189–1194)

### Wauheska Speed Car

THE Wauheska Motor Co. of Wauheska, Wis., built a Diesel-powered automobile intended for speed trials at Daytona, Fla. This was done in cooperation with the Hemphill Diesel Schools. The engine is rated at 140 to 150 hp and is a standard stock truck engine of the Wauheska Motor Co. Its most interesting feature is the combustion chamber located in the cylinder head and made of a single alloy casting with the chamber itself, a sphere connected to the cylinder by a tangential Venturi-shaped outlet. The combustion-chamber insert is in direct metal-to-metal contact with the head and frame of the engine only at the base flange, all the other walls being insulated by an air space so that the combustion chamber heats promptly and remains constantly at ignition temperatures as soon as the engine is started. This fact, combined with the high turbulence of the air compressed in it, assures prompt and clean ignition at all operating speeds.

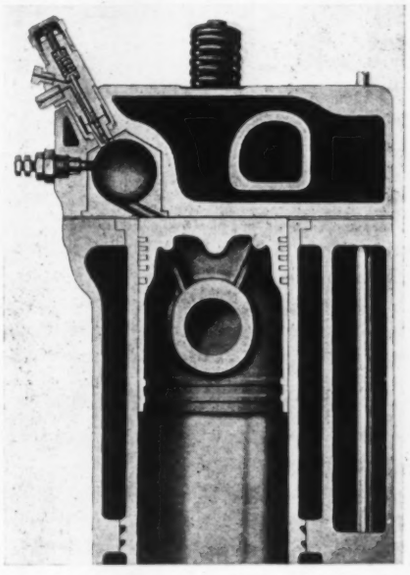


FIG. 2 WAUHESKA COMBUSTION CHAMBER AND CYLINDER

Another feature attributed to the "Comet" combustion chamber is the automatic regulation of the speed of combustion which occurs as a result of the increase in the rate of swirl of the turbulent air as the speed of the engine itself increases.

The fuel is injected directly into the combustion chamber through a pintle type injector, and the entire charge is burned in this spherical space, thus differentiating this type of construction from the usual precombustion chamber in which only a small portion of the charge is burned and the major portion ignites in the clearance space above the piston. (Abstract from a publicity release by manufacturers, 3 pp., 3 figs.)

### Power Alcohol

THERE are many angles to this problem—technical, economic, and, occasionally, outright propaganda.

There has been considerable difference in the conclusions reached by groups studying the straight technological phases of the proposal. Presumably, disinterested people more concerned with the use than with the supply of motor fuels get entirely different results from their experiments, but this might have been expected when it is recalled that road tests on fuels are not easy to perform, that, in fact, really worthwhile data can be secured only by technical observers, and then only with special equipment and after considerable experience.

With regard to sources of alcohol it is stated that when the proposal that alcohol from corn should be used in motor fuels was first heard the average price received by Iowa farmers was of the order of 12 to 14 cents per bushel. The prices realized for December 15, 1934, corn (U. S. Department of Agriculture) was 85.3 cents. As approximately 25 U. S. gal of 95 per cent alcohol are derived from a bushel of corn, the influence of these fluctuations on the cost of fuel alcohol would be material. On the side of economics the plans involve enormous Federal subsidies for the construction of alcohol manufacturing plants with no possible guarantee of self-liquidation. The erection of alcohol distilleries that might have operated in a year of large crops and low prices but remain idle

under crop shortage or under high prices is scarcely economic and such conditions recur.

Not enough has been said about how the farmer may find himself confronted with increased expense because of the advance contemplated in the value of feed corn, of the competition from brewers' grains and other stock foods, and of corn oil produced in much greater quantity as a by-product and meeting other vegetable oils on the market. Further, it must be remembered that a great many farmers raise no corn and could not participate in any advantages there may be in higher corn prices to offset their costs. Thorough studies at several state experiment stations show the plan to be a losing venture for the state as a whole when a balance is struck between total income and outgo. (Editorial in *Industrial and Engineering Chemistry*, vol. 27, no. 2, February, 1935, pp. 119–120)

## LUBRICATION

### Lubrication of Aircraft Engines

THE author discusses a hypothetical engine and its lubrication. The rated speed of the engine results in an average piston velocity of about 2400 ft per min, and this gives a rather high unit loading on the bearings. In spite of the fact that the best advertised oil is being used in the engine, the bearings persist in showing bright spots and cracks in the material of the liners. This is most annoying, and a conference of experts decides that both the oil grooves (or lack of them) and the bearing material are at fault. Some one computes the *PV* factors and shows that they are all wrong when judged by the published standards. The lubricant people solemnly aver that the oil meets specification requirements in all respects, and, moreover, is the "finest lubricant" ever produced by the refinery. The criteria for judging the virtues of the "finest lubricant" are extremely vague. The whole situation is most disturbing, for nobody appears to have any very definite notion of how to analyze the difficulty.

In sheer desperation, a "freak" kind of oil is used as a last resort, and all are elated to discern a distinct alleviation of the trouble. Examination of the oil-specification test data discloses nothing unusual except, perhaps, a failure to pass the emulsification test, a matter of scant import. Presently, under vows of secrecy, it is learned that the oil has been "compounded" with some mysterious ingredient. Tests in an unprejudiced machine show that the "compounding" has added to the base oil a surprising ability to carry-on under difficult conditions, and that for given conditions of unit loading $P$ and rubbing velocity $n$, the coefficient of friction $\mu$ is a function of viscosity $Z$, as long as a fluid film separates the bearing and journal.

$$\left(\frac{P}{N}\right)\mu = f(Z)$$

The fact that these functions differ in marked degree for the original and "compounded" oils indicates a need for intensive investigation of this phenomenon.

The immediate problem is in the combination of a compounding agent for improved load-ability in the region of film-boundary lubrication, plus an agent for improving (reducing) the viscosity ratio or temperature slope, plus the best available base oil, which in this country is probably represented by a solvent-treated Pennsylvania stock, the resulting material to have a maximum of oxidation stability in a high-output aircraft engine.

It is suggested that progress in the study of load-ability in film-boundary conditions would be accelerated if the various methods of testing this quality could be divorced from bias due to peculiarities in the fluid-mechanism of the means provided for supplying the oil to the bearing surfaces. Use of the Kingsbury or Michell slipper-bearing construction or application of the principles involved to a cylindrical journal and a partial bearing ring would probably eliminate many of the present discrepancies in test results and greatly facilitate the progress of a proper understanding of the problem. This matter should be handled by cooperative action from which predetermined bias has been rigidly excluded.

The problem of piston-ring gumming and oil sludging in service becomes increasingly difficult as the power output and temperature level is increased. However, it has been amply demonstrated that satisfactory performance in this respect can be obtained without material sacrifice of other desirable characteristics. When this optimum condition is obtained, a very real benefit is realized in reduced wear and increased service between overhauls. One operator is obtaining 700 hours of service between major overhauls without any intermediate "top" overhaul and the results appear to be entirely acceptable. (Paper before Metropolitan (New York) Section of the Society of Automotive Engineers, by R. F. Gagg, abstracted through *Metrosection Accelerator*, January-February, 1935, 5 pp., illustrated)

## POWER-PLANT ENGINEERING

### Schmidt Propeller Suction-Draft System

IT IS claimed that the use of the Schmidt propeller suction-draft system can save from 10 to 20 per cent of fuel, or that, on the same grate as before, a larger amount of coal can be burned. Other advantages are enumerated in the original article. The apparatus is illustrated and shows a four-bladed propeller to be installed in the stack. No detailed description as to the shape of the blades, etc., is given. (*Schiffbau*, vol. 35, no. 23, Dec. 1, 1934, pp. 392–393, 6 figs.)

### The Peak-Load Problem

THE article deals primarily with the British conditions and makes reference to the Weir report of 1926. The day will soon arrive when the division of stations into two classes, depending on whether they are operating on base or peak load, will also be extended to their design. Prof. F. G. Baily has suggested that power generation should take place at the pit head and not near the load centers. In the case of such stations having a low load factor the absence of large quantities of circulating water is of less importance than when a base load is being dealt with, especially since economy in operation need not be a determining factor, nor need the cooling arrangements be so elaborate.

Another solution is that recently adopted in connection with the utilization of certain blocks of water power. In Switzerland, Germany, and other countries, water power has generally been considered as a means of supplying the base loads and of providing a method of insuring an even flow of power often in large quantities throughout not only the whole of the 24 hr but of the year. Such a procedure is not applicable in Great Britain. Several plants are referred to including the Galloway Water Power Co., of which the engineering details have been recently published. In this latter plant this policy will enable resources amounting in the aggregate to some 21,500 kw to be developed without any extensive civil-engineering works, the result being that the cost of construction would compare favorably with that of steam plants. The conditions for meeting the winter peak will also be favorable, since three times the amount of water is available at that period than

in the summer, and as the peaks are less at week-ends than at other times, it will be possible to store water during that time for use on the other five and a half days. In a word, the underlying principle of the scheme is to enable an industrial load to be supplied for eight hours a day during the winter. (*Engineering*, vol. 139, no. 3601, Jan. 18, 1935, pp. 65–66)

### Heat Loss With Self-Contained Economic Boilers

ECONOMIC boilers are often preferred to the longer cylindrical types because of saving in floor space. For example, a battery of economic boilers with a middle firing aisle serving opposite furnaces may produce twice the evaporation of a Lancashire boiler set occupying equal room, without taking into account the economizer space.

As regards use of economizers with an economic boiler it is stated that unless some method of heat recovery from the flue gases is installed no economic boiler can be as thermally efficient as a Lancashire boiler complete with economizer. Otherwise the gases leave the economic boiler directly from the fire tubes and are necessarily at a high temperature, usually around 650 F, and this is uneconomical.

The author discusses next the problem of how to prevent heat loss while avoiding the use of accessories occupying further space or detracting from simplicity of arrangement and operation. Some compact feedwater-heating arrangement may be fitted in the smokebox uptakes, but the author does not like this method. On the other hand, in the new Howden-Johnson marine cylindrical boiler, an important feature is included which might be adopted in self-contained economic boilers. Fig. 3 shows an outline of the arrangements.

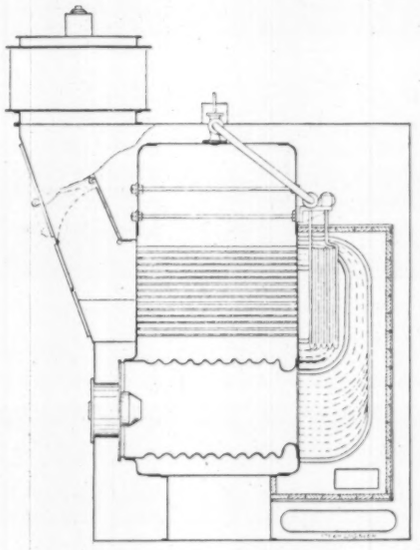


FIG. 3 HOWDEN-JOHNSON SCOTCH BOILER WITH AIR JACKET AND COMBUSTION-CHAMBER SUPERHEATER

In the majority of steamers the Scotch cylindrical marine boiler is retained, chiefly because it is a complete unit which costs little for maintenance and is not very susceptible to indifferent water supplies, but the submerged combustion chamber is something of a disadvantage in some respects, besides considerably raising the cost of construction. In the new boiler this feature is absent, and this is more or less compensated for by water-tube walls in a dry-back combustion chamber and by heat recovered from waste gases. From the lower end of the back end plate the water-wall tubes curve into the combustion chamber and rejoin the end plate below the water level. Then the whole of the boiler is enclosed by a casing through which draft from the air heaters flows on its passage to the furnaces. There is, therefore, no occasion to insulate the boiler shell, and heat radiated from all the boiler parts is absorbed in the furnace draft. The arrangement should be remarkably efficient, but for present purposes it will only be necessary to consider the water-tube wall which could be applied to economic boilers.

Evidently the new boiler, when stripped of its parts, is very much the same in principle as an economic boiler and there seems to be no reason why water-tube walls should not be added to self-contained economic boilers, and possibly to the brick-set types.

In Fig. 4 is shown a convenient adaptation of the water-tube wall principle to the ordinary type of self-contained economic boiler in which the shell of the dry-back combustion chamber is an extension of the boiler-shell end, and of the same diameter. Within the brickwork the water tubes may be spaced as closely as convenient, or as may be preferred, and continuing as far toward the combustion-chamber sides as may be expedient with regard to free expansion and contraction without strain. Simplicity rather than maximum efficiency is aimed at. Detachable tubes should not be considered; simple expanded tubes should serve and these should never leak once rightly set. In the arrangement of superheating tubes shown in Fig. 4 much of the length is not in active service, but this is a small point in view of the convenience of having the joints accessible at all times.

The author briefly discusses the possibility of scale formation in the water tubes, particularly where there is very little room for water-treatment tanks. (J. S. Gander, *The Steam Engineer*, vol. 4, no. 5, February, 1935, pp. 206–207 and 195, 3 figs.)

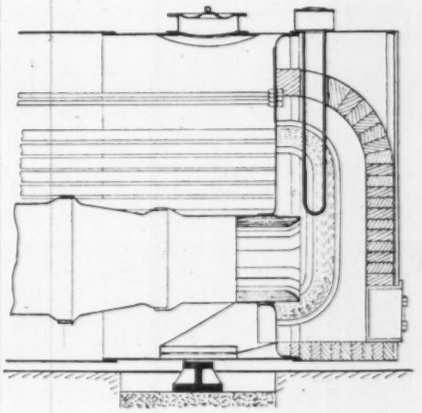


FIG. 4 SELF-CONTAINED ECONOMIC BOILER FITTED WITH WATER-TUBE WALLS IN COMBUSTION CHAMBER AND ORDINARY SUPERHEATERS

### The Rowan Gotaverken Exhaust Turbine System

THIS system includes a turbine operated by the exhaust steam from a reciprocating engine and arranged to drive a compressor by which the steam exhausted from the high-pressure or intermediate cylinder is raised to a higher pressure and temperature and thence returned to the receiver of the following cylinder. Because of this operation a considerably higher thermal efficiency is obtained from the combined plant, or, alternatively, a greater output with the same fuel consumption. It is said that the saving of fuel which could be effected in this way is in round figures 20 per cent for a plant using saturated steam and 16 per cent for one using superheated steam. The equipment has been fitted to seven vessels and a number of tests have been run by the makers and by Dr. A. L. Mellanby, of the Royal West of Scotland Technical College. The results of tests with superheated and saturated steam as well as indicator cards are given in the original article.

As to the detail, it is stated that the turbine and compressor are mechanically independent of the main engine and do not require to be cut out when going astern or maneuvering as they always run in the same direction, no matter which way the main engine is running.

Non-return valves are provided in a chest between the high-pressure exhaust and the medium-pressure receiver in the

case of a triple engine, and the steam automatically passes through these direct from high-pressure to medium-pressure cylinders, when the compressor is not working. When it is in action it raises the pressure in the medium-pressure receiver sufficiently to keep these valves shut. A low-pressure-steam surface feedwater heater is provided to take steam from the low-pressure-cylinder exhaust before the turbine and drain to the main condenser. The heater compensates for the lower condensate temperature due to the higher vacuum, and, of course, is only practicable on account of the difference in pressure arising between the low-pressure exhaust pressure and the main condenser when the compressor is in use. Some of the details of the test are given in the original article. (*Engineering and Boiler House Review*, vol. 48, no. 6, December, 1934, pp. 425–428, 5 figs.)

### Velox Steam Generator and Blast Preheater in Steel Mills

THE article shows a generator adapted for oil firing. As usual with this type of boiler, an oil pump forces oil into the burner where it is mixed with a blast of air and burned in a combustion chamber under the boiler at a constant pressure of 2.5 atm abs. The gases of combustion go to a steam superheater and thence with the pressure of 2.3 atm abs into a gas turbine which operates the blower providing the combustion air.

Should the gas turbine not have sufficient power to satisfy the requirements the blower may be boosted by means of a motor attached from the other side. A separate motor drives the oil pump and the boiler-feedwater pump. The gases which leave the gas turbine with a temperature of about 490 C go to an economizer where they flow with a velocity of about 90 m per sec and are discharged into the atmosphere.

The water driven into the economizer by an electrically operated pump flows in the economizer from top to bottom and then goes to the boiler-feedwater pump which delivers it to the lower end of the evaporator tubes. The hot mixture of steam and water discharged by the boiler goes into a steam separator where the steam is separated from the water and is sent to a superheater and whatever device it may drive, while the water from the separator is delivered to the circulating pump and operates therefore in a closed cycle. The water circulation, irrespective of the load on the boiler, constitutes from 10 to 15 times the maximum amount of steam generated.

In the steam generator working on normally cleaned blast-furnace gas the air of combustion and the gas are compressed in an axial blower. It is stated that dust deposits were very small as compared with what happens in conventional boiler plants.

In this connection may be mentioned a special plant built according to the Velox principle for heating the blast in a blast furnace with a daily output of 1000 tons. This has been installed side by side with the conventional plant consisting of three brick blast preheaters and an ordinary boiler unit heated by blast-furnace gas and used for driving the blowers.

The new plant consists of a Velox boiler and superheater to which are attached three metal blast preheaters. The gases of combustion are cooled in the boiler and superheater to about 815 C, and are further cooled in the first blast preheater to 398 C, whereupon they are sent through the gas turbine and finally through the second and third blast preheaters. The velocity of flow of both the air and the exhaust gases in the blast preheaters is high and hence the heat transfer is also high and the blast preheaters need to have only moderate areas of heating surfaces. The loss of pressure required for generating these high velocities and driving the gas turbines is taken care of by means of two compressors, one for the exhaust gas and the other for air. Both compressors are driven by the gas turbine.

To start the plant an auxiliary steam turbine is used; it drives the water-circulation pump for the Velox boiler. The air for the blast is driven through the blast preheater by the blast-furnace blower. The heat-transfer surfaces in the first and second blast preheaters contain tubes made of standard soft steel, whereas those used in the third preheater are made of a steel capable of resisting temperatures of from 815 to 870 C. It is claimed that notwithstanding the customary apparatus used, the total efficiency of the Velox blast preheaters is higher than that of similar machinery of conventional design, this being due to smaller losses and lower gas-exit temperatures. Fig. 6 in the original article shows diagrammatically a comparison between the Velox blast preheater plant, consisting of a steam generator and blast preheater, and a conventional plant with three brick blast preheaters and a standard type gas-heated steam boiler. This is intended to show the saving in cost and room effected by the use of the Velox plant. (*Stahl und Eisen*, vol. 54, no. 49, Dec. 6, 1934, pp. 1263–1265, 6 figs.)

## RAILROAD ENGINEERING

### Diesel and Steam Locomotives for Building Industries

THE equation for the drawbar pull of a locomotive in terms of output $N$ in horsepower and speed $V$ in kilometers per hour is $Z = 270\ N/V$ in kg. With $N$ constant this equation gives a hyperbola on the $Z$-$V$ diagram. The output of the engine of a steam locomotive is obtained usually either above or below the best speed for which the machine has been designed. The $Z$-$V$ diagram therefore gives a flattened-out hyperbola. The most favorable speed in the ordinary type of locomotive for building industries is obtained with a cut-off of 30 to 35 per cent. In this case the average indicated pressure $p_i$ is from 1/2 to 6/10 of the boiler pressure $p$, and therefore the indicated drawbar pull at the periphery for a twin-engined locomotive is $Z_i = 0.5$ to $0.6\ p\ d^2s/D$, where $d$ is the diameter of the cylinder, $s$ the stroke, and $D$ the diameter of the driver wheels. The drawbar pull as a function of the output of the engine is limited in the upward direction by the maximum cut-off of about 70 per cent and amounts to $Z_{i\max} = 0.85\ p\ d^2s/D$. Even when the maximum speed $V_{z\max}$ corresponding to the maximum drawbar pull according to the equation is set low, the drawbar pull cannot be increased. In the $Z$-$V$ diagram the flattened-out parabola breaks off and passes into a straight line parallel with the axis of velocities.

The Diesel locomotive is equipped with a variable-speed gear box for transmitting the power from the motor to the driver wheels. Because of this the $Z$-$V$ diagram is not a curve but a line formed in several stages corresponding to the stages of the gear drive. The output of the motor running at full rotary speed is constant and the maximum drawbar pull for a given output of the motor is limited only by the minimum speed permitted by the gear drive. Because of the necessity of starting the vehicle, this lower speed is below that which, for a steam locomotive of equal power, corresponds to the maximum drawbar pull with a given motor output $V_{z\max}$. Because of this, the greatest drawbar pull of a Diesel locomotive is correspondingly greater than the greatest drawbar pull of a steam locomotive having an engine of the same output. The drawbar pull of a locomotive is limited also by the frictional weight. Under normal conditions the friction permits utilization for drawbar pull only from 1/5 to 1/6 of the locomotive weight. This amount can be increased by sanding. Therefore, the

Diesel locomotive must be built heavier than a steam locomotive of the same output in order to utilize the greater drawbar pull which its propelling machinery develops.

For large construction works with a 60-cm gage and considerable upgrade stretches, a 60-hp steam locomotive seems to be the most desirable type. Its *Z-V* diagram is shown in Fig. 5. The maximum effective drawbar pull

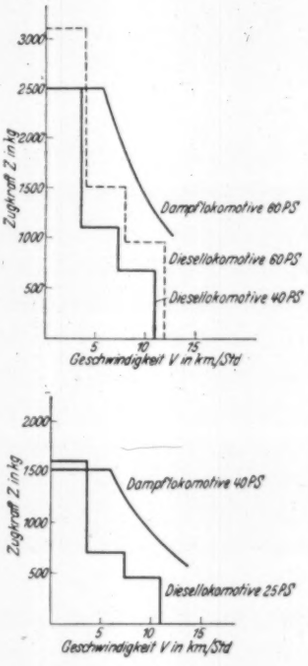



FIG. 5 (TOP) AND FIG. 6 (BOTTOM) DRAWBAR PULLS OF DIFFERENT TYPES OF LOCOMOTIVES AT VARIOUS SPEEDS OF RUNNING (*Zugkraff* = drawbar pull; *Dampflokomotive* = steam locomotive; *Diesellokomotive* = Diesel locomotive; *Geschwindigkeit* = speed.)

on the periphery with the amount of power set forth is about 2500 kg.

The machine has a service weight of about 10 tons. The limit of its friction without sanding is at the most 2000 kg. The 60-hp Diesel locomotive with velocity stages of 4.8 and 12 km per hr has a maximum effective drawbar pull of about 3100 kg (Fig. 5). It has a service weight of 13 tons, so that the limit of its frictional weight is about 2600 kg. The maximum drawbar pull exceeds that of a steam locomotive by about 25 per cent.

The Diesel locomotive which has the same maximum drawbar pull as the 60-hp steam locomotive is the 40-hp type with a first speed of about 3.5 km per hr. Its *Z-V* diagram is shown in Fig. 5. Its service weight is about 10 tons, or the same as in the 60-hp steam locomotive. The first cost of the 60-hp Diesel locomotive is nearly twice as great as that of the 60-hp steam locomotive.

This is a disadvantage which often leads to unwillingness of the purchaser to buy such a locomotive, but this disadvantage is sometimes canceled by such general advantages of the Diesel engine as lower operating costs, constant readiness to run, and elimination of the necessity of supplying feedwater which is difficult to procure at times. The first cost of a 40-hp Diesel locomotive of the standard type is just about equal to that of a 60-hp steam locomotive. The question is, therefore, to what extent the steam locomotive can be replaced by a Diesel locomotive having a smaller motor output, but the same maximum drawbar pull. On larger constructions with the 60-cm rail gage the weight of a train is on an average about 60 tons, which corresponds to from 15 to 20 gondolas of $1^1/_2$ to 1 cu m capacity.

Because in the majority of cases the rails are not laid very carefully, the velocity of the train can seldom exceed 10 km per hr. The train resistance is usually 10 kg per ton of train weight. Under these assumptions the steam locomotive with the 60-hp engine and a drawbar pull of 2000 kg can pull a train up a 2 per cent grade. The speed under these conditions, as shown by the *Z-V* diagram, Fig. 5, is about 6.5 km per hr. On the level with a straight track and the train running at 10 km per hr a drawbar pull of 1400 kg will be developed, and the train will require only 600 kg. The steam locomotive is therefore greatly under-loaded on runs that are made in level country.

The Diesel locomotive with a 40-hp engine has, like the 60-hp steam locomotive, a maximum frictional drawbar pull of 2000 kg as its weight of 10 tons is the same. It can therefore also draw the train up an incline of 2 per cent, but according to the *Z-V* diagram only with a speed of 3.5 km per hr. On the other hand, on the level, it will develop, at a speed of 10 km per hr, a drawbar pull of 650 kg which is entirely sufficient to pull the train. The 40-hp Diesel locomotive therefore carries a full load on level stretches.

If the maximum grades are more than 2 per cent the weight of the train will have to be reduced in both cases.

From this it would appear that the only difference between the 40-hp Diesel and the 60-hp steam locomotive is that on a grade the former will run with a speed of 3.5 km and the latter 6.5 km per hr. To what extent the higher velocity is valuable must be decided on the merits of each individual case. In general, it may be said that unless the length of steep grades is a substantial part of the total length of the tracks, the performance of the 40-hp Diesel locomotive comes close to that of a 60-hp steam locomotive, and where the track is predominantly level, a 40-hp steam locomotive may be used, as its drawbar pull when running at 10 km per hr amounts to 900 kg. In such a case the superiority of the Diesel locomotive in that it can pull greater loads at lower speeds fails to be of material value, whereas the steam locomotive has the added advantage in that its mechanical efficiency is better because of the direct transmission of power.

On smaller jobs where smaller locomotives are used the distance over which they operate is usually so short that the matter of duration of runs is of no importance. Fig. 6 shows how a 25-hp Diesel locomotive operating on first speed at 3.5 kg per hr has the same maximum drawbar pull as a 40-hp steam locomotive. Where a still smaller unit is contemplated, the steam locomotive completely fades out of the picture.

From the aforementioned considerations, it would appear that Diesel locomotives should be compared with steam locomotives for speeds of 3.5 km per hr. Speeds in excess of 10 to 12 km per hr are used so seldom that they need not be considered at all. Where the outputs of a Diesel locomotive are less than 40 to 25-hp the comparison of their drawbar pulls with those of the steam locomotive is not quite so favorable and a 10 per cent reserve of power must be made. [Attention is called to the fact that in a previous paragraph it has been said that at outputs lower than 25-hp the steam locomotive fades out of the picture, while in this paragraph it is said that the drawbar pull of the steam locomotive of less than 25-hp is better than that of the Diesel locomotive.] (H. Schmidt, *Der Bauingenieur*, vol. 15, no. 31/32, Aug. 3, 1934, pp. 311–312)

## SPECIAL PROCESSES

### Flow of Metal During Extrusion

THE author considers the extrusion process of non-ferrous metals as one of the most important of the hot-working processes. Extrusion can be carried out by the direct process or by the inverted process and the author shows an experimental process arranged for the latter method. A number of attempts have been made to study flow behavior by the use of composite billets and the

author refers to his experiments and those made by Unckel.

A method has been developed in Germany whereby billets are cut in half longitudinally and a rectangular grid is cut on one of the inner faces. Curves are filled with graphite and the two halves are wired together, heated, and then partly extruded in the ordinary way. Since the cut axis is one of symmetry with respect to the flow the billet behaves as if it were whole. The two halves separate readily after extrusion and from the distortion of the grid accurate analysis can be made of the deformation which has occurred.

The author refers briefly to the inflowing of the side of the billet at the rear end and the practice now followed in order to avoid this extrusion defect. In inverted extrusion a zone of deformation is developed at the die entry which as extrusion proceeds is transferred along the length of the billet. It is believed that by suitably shaping the die orifice the tendency for the center to extrude ahead of the sides could be reduced. It seems that this can be done by an acutely conical die entry.

The matter of pressure and influence of die shape is discussed and two tables are given—one showing power consumption for various die forms and the other pressure required for extruding tin through various shapes of die. (Paper by C. E. Pearson read before the Institute of Metals, abstracted through *Machinery* (London), vol. 45, no. 1157, Dec. 13, 1934, pp. 401–405, 19 figs.)

### Copper-Alloy Die Castings

IN SPECIFYING copper-alloy die castings undercuts and sharp corners should be avoided. Generous fillets and webs add strength to the part and assist in producing a better casting. The use of inserts should be confined to those applications where special qualities are required.

Minimum wall stocks in a cylindrical portion or the main part of a casting should be $^3/_{32}$ in., although portions of a casting may have a $^1/_{16}$-in. wall. Variations from drawing dimensions must be plus or minus 0.003 in. Desirable draft for side walls and cores is 0.020 in. per in.

On the outside walls draft, as is sometimes desirable, may be 0.005 inch per inch of length. The wall intersections should be liberally filleted as should also the area around the base of bosses. Minimum size of cored holes is $^1/_8$ in. diameter. In general, holes from $^1/_8$ to $^1/_4$ in. diameter can be cast one and one-half times their diameter in depth; larger holes than this can be cast deeper. External threads, if of coarse pitch, may be cast, but have to be chased, while internal threads cannot be cast. Spur-gear teeth of 24-pitch or larger can be cast and then shaved to size.

The production of copper-alloy die castings is divided into two distinct fields—permanent mold or vacuum castings of aluminum bronze, and pressure die castings of brass, there being a number of alloys available in each grouping. In the vacuum die-casting process (aluminum bronze) the alloy is drawn by vacuum into a steel die from below the surface of the molten metal. The little aluminum oxide which is formed on the advancing surface of the metal is deposited in a thin film upon the walls of the die cavity. Thus, a casting is formed which is free of aluminum oxide within its body metal.

The resistance of copper alloys to shocks and unusual stresses is demonstrated in the aluminum-bronze die-cast swivel bracket for an outboard motor which withstands the strain of outboard-motor racing. (Allen F. Clark in *Machine Design*, vol. 6, no. 11, November, 1934, pp. 24–26, 6 figs.)

## STEAM ENGINEERING

### Stephen Marine-Engine Trials

THE engine, described in *Engineering*, Vol. 136, 1933, p. 489, is a three-cylinder semi-uniflow type. It was installed in the *Loch Ranza* and the present article gives results of tests, particularly sea trials, shop tests having been previously run. The tests are given in the original article in the form of tables.

A test with full-load displacement of 12,200 tons gave the following results: Speed, 11 knots; propeller revolutions, 67 per min.; indicated horsepower, 1875; coal consumption, $22^3/_4$ tons per day or 1.135 lb per ihp-hr. The coal used was stated by the suppliers to have a calorific value of 14,000 Btu per lb and was reported to be fast burning. The ash content obtained from the supplier's analysis was from 5 to 6 per cent. (*Engineering*, vol. 139, no. 3599, Jan. 4, 1935, p. 20)

## VARIA

### New Means of Producing Extremely High Temperatures

IT IS stated that electron bombardment and the sun furnace make it possible to obtain temperatures limited only by the evaporation of the sample. The former applies to the heating of solid bodies and is substantially operated, as follows: A tungsten wire is heated in a vacuum to 1800 C. Electrons will be emitted from the wire. The wire is used then as a cathode and the container to be heated as an anode. The electrons from the wire strike the container and heat it to as high a temperature as desired. The anode may be a tube which contains the sample to be investigated or a crucible.

The only temperature limit of this heating method is set by the melting and evaporating of the container and the sample. Instead of a wire a pointed cold cathode may be used.

The principle used successfully in the sun furnace built in the Zeiss Works in Jena is as follows: A large plain mirror about 100 in. in diameter follows the motion of the sun and reflects the radiation from the sun to a large hollow searchlight mirror 100 in. in diameter. The entire energy is then concentrated in a small focal spot of the hollow mirror which has a diameter of only 8 mm and it is here that the substance to be investigated is placed.

The temperatures obtained with the sun furnace will melt every solid material known. The author has melted, for instance, zirconium and magnesium oxides into clear glasses at temperatures of more than 3000 C. The main advantages of the sun furnace are: Heating is done under very pure conditions, and in an oxidizing atmosphere; no electric or magnetic fields are present which may disturb the reactions or spectra to be studied; a very short time is required for obtaining the highest temperatures, more than 3500 C being reached, for instance in about 30 sec. By placing a quartz glass bulb over the sample it is possible to use the sun furnace for work in a reducing or neutral atmosphere, or in a vacuum.

Some other methods of obtaining very high temperatures are the use of one or several explosives, discharging large condensers through a very thin wire, burning of aluminum, firing a bullet into a closed cylinder, etc. All these methods will give high temperatures for only a very short interval, and therefore have not been discussed in this paper.

The original article contains a table giving melting points in degrees centigrade for some elements and compounds used in high-temperature work. (Willi M. Cohn, in *The Glass Industry*, vol. 15, no. 7, August, 1934, pp. 149–150, 5 figs.)

# LETTERS AND COMMENT

*Brief Articles of Current Interest, Discussion of Papers, A.S.M.E. Activities*

## Control of Distribution

To the Editor:

THE paper by T. H. Brown on "Control of Distribution" (Mechanical Engineering, December, 1934) has shown a most urgent need for the application of statistical methods to the field of distribution. But I wish to comment on his application of the "methods of attributes" (p. 719) and the "analysis of variance" (pp. 721–722).

Professor Brown states that the "determination of an attribute is not made through a process of measurement. It consists simply of a process of counting." Perhaps the following statement would be more acceptable.

The characteristics observed in a sample from a population are of two broad classes: (1) Presence or absence, and (2) quantitative. The first is the sampling of attributes, while the second is the sampling of variables, both measurements of a *kind*. In one case the measurement could be plus or minus, while in the other it could be any real finite and continuous function describing the variate.

In the analysis of variance Professor Brown has given correctly Prof. R. A. Fisher's statement[1] of variance; i.e., variance $= \sigma^2$. Since this is true, then "$n\sigma^2$ = the variance = $V$" cannot be true. So his formula $n\sigma^2 = \Sigma x^2 - (\Sigma x)^2/n$ is not the variance but is the sum of the squares of the deviations of the observations from their mean. Also he has made no allowance for degrees of freedom in his equations, i.e., $n - 1$, instead of $n$ as the denominator, for computing the variance.

If $V = n\sigma^2$ be referred to as the sum of squares we find his Equation [1] to be correct, then the next equation $V_{\text{means}}$ (between districts) is wrong in two senses: $(\Sigma x/n)^2$ should read $\Sigma x^2/n$, and in the second part the exponent $(\ )^2$ should be removed and written as $\Sigma x^2/n$. Also $1/n$ is not required to satisfy the relation. If an estimate of the variance between districts is desired the value $1/n$ should be replaced by $1/(n-1)$, as shown correctly in his table at top of the right-hand column of p. 722.

Professor Brown's computation of the sum of squares between means of districts, 17,565, quite obviously does not follow the equation commented upon in the foregoing, but uses the relations I have given. His numerical work is correct, however. Snedecor has a superior method for testing the significance of the mean squares (variance and not "mean variance" as erroneously stated). Professor Brown does not indicate that the "remainder" or interaction is the best estimate of the experimental error in the data and for that reason the other mean squares are compared to it as a ratio in testing the significance of a chance difference between the selected combinations.

Furthermore, the paper does not seem to make clear the foundation upon which the argument has been based. In other words, the paper fails to disclose the fundamental basis upon which the selected statistical methods rest.

E. Dillon Smith.[2]

To the Editor:

I am replying to the letter of Mr. Smith for two reasons: (1) to acknowledge a change in definition which he has noted in my equations, and (2) to comment on his discussion of my paper.

Mr. Smith is quite correct as far as the mathematical point is concerned. In my article I have apparently shifted the definition as stated in the left-hand column on page 721 "The measure of these variations is taken as the square of the standard deviation. This is known as the variance." On page 721 in the right-hand column the definition given is "$n\sigma^2$ = the variance = $V$." In order to unify the terminology I am entirely agreed that the first definition should hold. In such a case, $V$ would be defined as $n$ times the variance. Thus, the definition on page 721 should read "$n\sigma^2 = n$ times the variance = $V$." When this has been done, there is only one further comment. In obtaining the relationship $V_{\text{within columns}} = V_{\text{whole}} - V_{\text{means}}$ given on page 722, an additional $n$ must be introduced to balance the factor $1/n$ given at the bottom of page 721. This added factor arises through the sampling error present in the mean value of a series of numbers. The question of degrees of freedom which Mr. Smith seems to be so worried about is not included in the equations. That was not my intention, as my desire was simply to provide an understanding of the relationship between the various quantities which are needed in obtaining the table of mean values including the degrees of freedom. This is given at the top of the right-hand column on page 722. I believe, as Mr. Smith indicates, that the numerical work is correct. With the change in definition I believe that he will find the mathematics of the relationships between the various quantities needed also is correct.

In regard to attributes and variables, Mr. Smith has lifted out of my paper portions of statements which seem to have quite different implications than those which I indicated. My full sentences, from which he quotes only a part, together with the preceding one are "Thus, in the field of distribution, a radio manufacturer would like to know in a given market area the number of families which possess a radio. Determination of this number is not made through a process of measurement. It consists simply of a process of counting." Confusion evidently has arisen over the meaning of the word "measurement" as used. My whole statement seems to me to be reasonably clear. In his letter Mr. Smith seems to have followed Yule's statements[3] in regard to attributes and variables. Possibly it is this form of statement which he prefers.

Finally, Mr. Smith raises the question of the foundations of the subject which are not developed. Has he overlooked the limitations of space and time, as well as my objectives in writing? With a limited space available, it seemed to me

[1] (See "Statistical Methods for Research Workers," Oliver and Boyd, London, 1932, 4th edition, pp. 13 and 77. Also see "Calculation and Interpretation of Analysis of Variance and Covariance," by G. W. Snedecor, Collegiate Press, Ames, Iowa, 1934, p. 1.)

[2] Columbia University, New York, N. Y.

[3] See "Introduction to the Theory of Statistics," by G. U. Yule, Charles Griffin and Company, London, p. 7.

that an engineering society was very much more concerned with the manner in which some problems in distribution might be attacked rather than in a prosaic, logical development of technique. The foundations of the theory of variance Mr. Smith will find in the works he has cited in his letter. The foundations of the applications of this theory, together with other theories needed for the solutions of problems of distribution, comprise a part of the principles of business statistics. At present these are practically unknown.

THEODORE H. BROWN.[4]

## Jobs for Young Engineers

TO THE EDITOR:

The existing want of opportunities for employment for engineers is no longer news. The plight of those who search in vain for gainful occupations has been reiterated so often that the situation has come to be accepted by many as a matter of course which defies any attempts to improve it. Such an attitude of resignation, however, does not seem to befit engineers. Our Society, at least, refuses to believe that the situation cannot be helped to some extent, and is continually calling upon every resource at its command to relieve the condition. Its efforts indicate that it is especially concerned with the lot of the young engineer and the recent graduates. Their predicament is well deserving of special attention. Neither the Society nor the industry can afford to allow them to drift into other fields.

Some of the cases that have come to my attention are truly pathetic. However great the urge to help may be, one must capitulate to the inability to render assistance single-handed. Among the measures and steps that have been taken to ameliorate conditions, that of creating new opportunities for employment has, in my opinion, not as yet been sufficiently explored, and it seems that the cooperation of many could be enlisted toward this end. The problem is not dissimilar to that of finding new applications for a new product. Once an application is found, it is brought to the attention of both the salesman and the prospective users. Similarly, information about unorthodox opportunities for employment could be disseminated among both those who seek employment and prospective employers. We read often how one branch of business has followed the lead of one of its members and adopted a method which had formerly been scorned as unsuitable to the particular business. Engineering talent is not different in this respect. Department stores are one illustration. Not only are stores employing young engineers in increasing numbers, but those that are doing so find new uses for their services. The value of young engineers in business-administration work is also well established. There must be many instances in which a certain branch of business has found it profitable to use young engineers. If those members who know of such instances would pass the information on to the A.S.M.E. Metropolitan Junior Group Committee for the Investigation of New Industrial Fields (see MECHANICAL ENGINEERING, March, 1935, pp. 198–199), that committee would see to it that this information reaches those it is intended for. This will, I believe, prove to be a step in the right direction.

In his article on "Finding Work" in the November, 1934, issue of MECHANICAL ENGINEERING, S. S. Board cites the instance of a 60 per cent saving in the fuel bill by one manufacturer who attributes this saving entirely to the employment of two young engineers. I have often advised owners and superintendents who believed that their plants were too small to justify such an expenditure to employ a young engineer as an assistant to the operating engineer. His fitness for keeping records, for checking, and for observation, together with the ever-present desire to make himself useful, is bound to give results which will more than compensate for the small expenditure for which his services can be obtained. It may be difficult, as Mr. Board points out, to "sell the idea" to such prospective employers, but most certainly it is well worth the trying. If we can gather sufficient evidence to prove that it pays, it may not be so difficult after all.

ARNOLD WEISSELBERG.[5]

## Domestic Heating

TO THE EDITOR:

Mr. Drewry's paper[6] is interesting and is indicative of the high efficiencies attainable with solid fuels for domestic heating. Efficiencies higher than 75 per cent average depend upon heat recovery from the flue gases and, as in central-station practice, the gas temperature must not be reduced below the dew point, or corrosion and other difficulties will more than offset the gain in efficiency. Therefore, if efficiencies averaging 90 per cent for an entire heating season are to be regularly attained, a fuel of low hydrogen content must be used.

The low cost of solid fuels has not until within the past few years, been conducive to the development of highly efficient domestic-heating equipment. Increased competition in automatically controlled fuels has made the public "heat-conscious" and more attention has been directed toward efficiencies. To meet these conditions it has been necessary to develop, test, and improve equipment for burning solid fuels. As a result of this effort the domestic stoker has reached a point where dependable, automatically controlled, and regulated heat can be economically obtained with coal as a fuel.

The Norfolk & Western Railway Company, in cooperation with the coal producers on its lines, set up a testing laboratory to determine the adaptability of modern stokers to the use of Pocahontas and bituminous coals produced along its lines. During a series of 47 variable-load tests, low- and high-volatile coal from several different mines was used in four different stokers. The attention given the stokers was less than that expected of the average user.

An American Ideal Red Flash boiler No. 2-W-7 was used and the efficiencies were calculated on the basis of boiler output with no credit for radiation losses.

The average efficiency for the entire 47 tests was 62.7 per cent, with most of the efficiencies ranging from 56 to 68 per cent. The maximum secured on any individual test was 72 per cent. The manual attention given the fire during the tests was kept at a minimum with the object of obtaining results under the worst conditions that might occur in actual use. While more frequent attention, say daily, would have resulted in an improved average fire condition, such attention was purposely avoided.

The average coal consumed for the 47 seven-day tests was 993 lb, and the fire was cleaned an average of 2.2 times during the seven days. This figure includes the final cleaning on the last day preparatory to starting a new test. In a number of tests using the lower-ash coals, the only cleaning during the seven days was at the close of the test on the last day. The fuel bed was not broken up or disturbed in any way except when the fire was cleaned.

The program of tests conducted by the

[4] Professor of Business Statistics, Harvard University, Cambridge, Mass.

[5] Consulting Engineer, Jersey City, N. J. Mem. A.S.M.E.

[6] "The Application of Central-Station Practice to Domestic Heating," by M. K. Drewry, MECHANICAL ENGINEERING, February, 1935, pp. 103–109.

Norfolk & Western Railway has shown stoker firing of the usual heating boiler to give economical, automatic heat with a minimum of attention from the householder. Tests now being run using baffles in the flues to increase heat transfer indicate still greater economies to be gained from coal, stoker fired, if the boiler were designed expressly for stoker firing. The tests of the baffles have not progressed far enough to date for the publication of any figures.

W. S. GARRETT.[7]

TO THE EDITOR:

A few years ago automatic heat could be obtained only by the use of oil and gas, as automatic burners had not been developed for coal. During that period home owners desiring automatic heat were justified in paying the extravagant bills entailed.

That condition no longer exists. Since the development of coal burners, automatic heat with coal, with all of its advantages, has become in most localities the lowest-cost type of heating available, even lower than that of hand-firing of coal.

In all but a few localities coal has a very decided advantage over oil and gas. An analysis of fuel costs in the 40 largest cities in the United States indicates the average retail fuel costs per therm (100,000 Btu) to be as follows: for stoker coal, 1.9 cents per therm; for oil, 4.3 cents per therm; and for gas, 11.1 cents per therm.

Oil heat, by this comparison, costs 2.2 times as much as coal, while gas costs 5.8 times as much. Fuel costs are an important consideration. Fuel bills recur annually and must be kept at a minimum, within the range of the average household budget.

The stoker or coal burner with controls makes coal a completely automatic fuel in the matter of heat supply and regulation. Coal also has an advantage over oil and gas in the maintaining of comfortable heat. The coal fuel bed avoids the "off and on" heat of liquid or gaseous fuels which have no fuel bed. The heat of the fuel bed also avoids the well-known "cold 70" condition.

Mining and mine preparation of coal are receiving much more care than formerly. This has contributed to the cleanliness of coal. Added to this, dust treatment is now becoming commercial practice. With sealed coal receptacles and the elimination of manual handling, coal has become a thoroughly clean fuel. Smokeless combustion is inherent with stokers and proper furnaces.

T. A. MARSH.[8]

TO THE EDITOR:

Professor Seeley's paper[9] confirms the point that low load efficiencies are of major importance in establishing seasonal efficiencies of domestic-heating equipment. Central-station boiler units develop maximum efficiency at low loads, a characteristic which is desirable for domestic units. The paper also shows that actual tests in residence service, over a considerable period, are necessary to establish ultimate efficiency reliably.

The subject of domestic chimney drafts is interesting and suggests the use of various controls when fluid fuels are burned. To cope with negative drafts that occur in summer operation, equipment operating intermittently must employ fan apparatus to inject air until, at least, a draft is established within the heater. Back-draft diverters, if they permit discharge into the basement, would appear unsafe. Winds enhance chimney draft by creating about one-half of their velocity-head pressure in the home plus a suction induced by flow over the chimney top. Drafts may readily reach 0.2 in., and are often violently fluctuating. Whether bleeding air into the base of the chimney can produce even an approximation of constant furnace draft is a question, and it certainly will affect heat losses and the humidity and air-cleanliness problems. With solid fuels, variable chimney draft need not be a problem, for all regulation can be done by the draft door.

Regarding Mr. Marsh's statement of relative fuel costs, it is important that comparisons be made on costs of fuel quantities needed for average residences. In Milwaukee, quantities of 50 tons or more are delivered at 20 per cent less than domestic-fuel quantities. Domestic-stoker coal in Milwaukee costs only 2 per cent less than coke reported in the paper, a difference which may be exceeded by better efficiency and cleanliness.

As pointed out by W. G. Christy in the October, 1934, issue of MECHANICAL ENGINEERING, better data are needed of small-stoker performance. For the domestic use of caking fuels, tests in an actual residence over a long-time period, using coals having all combinations of caking, distillation, and ash-fusion characteristics, are recommended. The best tests known to date are those by Professors Young and Miller, of Purdue University, published in the 1931 World Power Conference report. They comprise 28 tests of small industrial stokers firinga n 87-hp Kewanee boiler, and show an average efficiency of 67 per cent and automatic operation for about 12 hr.

Mr. Sherman has previously used the plan of solving for total domestic heating costs, including investment charges as well as all operating costs. Table 7 of my paper[10] was submitted to illustrate the calculation, and to show that high fuel-utilization efficiency can pay new air-conditioning costs. It compares the installation described with its predecessor.

TABLE 8 INPUT-OUTPUT TESTS

| | | |
|---|---|---|
| **General Data** | | |
| Test number | 1 | 2 |
| Duration, hr | 69 | 72 |
| Dates | Sept. 18–21 | Oct 28–31 |
| **Temperatures** | | |
| Basement, F | 75 | 65 |
| Flue gas, boiler outlet, F | 510 | 425 |
| Flue gas, smoke-pipe outlet, F | 173 | 225 |
| Circulating water, outlet, F | 131.6 | 132.3 |
| Circulating water, inlet, F | 64.3 | 57.3 |
| **Flue-Gas Analysis (smoke-pipe outlet)** | | |
| $CO_2$, per cent | 14.4 | 12.7 |
| $O_2$, per cent | ..... | 7.5 |
| CO, per cent | ..... | 0.1 |
| **Coke fired** | | |
| Moisture, per cent | 3.45 | 10.0 |
| Ash, per cent | 8.0 | .... |
| Btu per lb | 12640[a] | 11787 |
| Total weight, lb | 257 | 317 |
| Weight per hour, lb. | 3.72 | 4.4 |
| Weight per hour per sq ft grate | 2.1 | 2.5 |
| **Ashes** | | |
| Number of times shaken | 3 | 4 |
| Frequency of shaking, hr | 23 | 18 |
| Total refuse removed, lb | 22.5 | 17 |
| Combustible in refuse, per cent | 18.5 | 9.5 |
| **Input and Output Data** | | |
| Circulating water, lb | 38000 | 42700 |
| Output to circulating water, Btu per hr. | 37100 | 44500 |
| Output, per cent of rated capacity | 37.1 | 44.5 |
| Output, per cent of average heating-season output | 116 | 140 |
| Input, Btu per hr | 47100 | 51800 |
| **Smoke-pipe performance** | | |
| Reduction of flue-gas temperature, F | 337 | 200 |
| Weight of flue-gas per lb coke, lb | 13.9 | 16 |
| Per cent of heat in coke transferred to room | 8.8 | 6.7 |
| Unit heat transfer, Btu/hr/sq ft/F | 0.5 | 0.6 |

[7] Mechanical Inspector, Norfolk & Western Railway Co., Roanoke, Va. Jun. A.S.M.E.

[8] Iron Fireman Mfg. Co., Chicago, Ill. Mem. A.S.M.E.

[9] See pp. 221–224 of this issue.

[10] See MECHANICAL ENGINEERING, February, 1935, p. 109.

| | | |
|---|---|---|
| Efficiency data | | |
| Heat absorbed by boiler, per cent... | 78.8 | 86.0 |
| Heat transferred to room by smoke pipe, per cent..... | 8.8 | 6.7 |
| Heat transferred to room by boiler (calculated) per cent..... | 2.5 | 2.0 |
| Space-heating efficiency, per cent... | 90.1 | 94.7 |
| Calculated losses at smoke-pipe outlet | | |
| Moisture in fuel, per cent..... | 0.3 | 0.9 |
| Hydrogen, per cent | 0.9 | 0.9 |
| Dry flue gas, per cent..... | 2.6 | 4.0 |
| Moisture in air, per cent..... | 0.1 | 0.1 |
| CO, per cent..... | 1.0 | 0.5 |
| Combustible in refuse, per cent... | 1.6 | 0.7 |
| Measured radiation loss to ash-pit, per cent.... | 4.0 | ..... |
| Unaccounted - for losses and errors, per cent..... | —1.0 | —1.8 |

[a] Calculated from heating value of similar coke used in second test.

After the paper was submitted, two three-day measured-input, measured-output tests were made.

Heat output was determined by flowing metered tap water through the boiler and noting its temperature rise before discard to the sewer. The water meter was checked at least twice daily, and the outlet-water temperature was recorded. Heating service was maintained during the second test by routing the discharge water through the radiator.

Heat input was learned by weighing coke feed and sampling the coke as used. Terminal errors were minimized by choosing a long period of test. Averages of the efficiency (Table 8) are thought to have an accuracy within 2 per cent.

The first test disclosed the point that appreciable heat losses into the basement floor from radiation through the grates occurred because ashes were removed daily and no insulation was present. Tests of water-evaporation rate at the floor showed this loss to be 4 per cent under conditions similar to those maintained in the test. During the second test, insulation reducing this loss was provided and ashes were permitted to accumulate. The boiler was cleaned before the second test.

These tests confirm the point that 90 per cent heating-plant efficiency is averaged in regular every-day operation.

M. K. DREWRY.[11]

[11] Assistant Chief Engineer of Power Plants, Milwaukee Electric Railway & Light Co., Milwaukee, Wis. Mem. A.S.M.E.

# A.S.M.E. BOILER CODE

## *Interpretations*

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following are records of the interpretations of this Committee formulated at the meeting of February 8, 1935, and approved by the Council.

CASE No. 527

(Annulled because of revision of Par. P-258)

CASE No. 765

(Annulled)

CASE No. 779

(Annulled)

CASE No. 802

(*Interpretation of Pars. P-104 and U-72*)

*Inquiry:* Is it permissible under the requirements of Pars. P-104 and U-72 of the Code to shape the scarfs of welding edges by flame cutting?

*Reply:* It is the opinion of the Committee that if the welding edges of steel plates, containing not to exceed 0.35 per cent carbon, are formed by flame cutting so that they are uniform and smooth, and are free from slag and scale accumulations, the welds may be applied thereon without conflict with the Code rules. The discoloration which may remain on the flame-cut surface is not considered to be detrimental oxidation.

# Revisions and Addenda to the Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later in the proper place in the Code.

The following proposed revisions have been approved for publication as proposed addenda to the Code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticism and approval from any one interested therein. It is to be noted that a proposed revision of the Code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

### REVISIONS

PAR. P-14. Revised:

P-14. *Tensile Strength of* [*Steel*] *Plate.* In determining the maximum allowable working pressure, the tensile strength used in the computations for [steel] plates shall be that stamped on the plates (NAMELY, the minimum of the SPECIFIED [stipulated] range), as provided in THE SEVERAL specifications [S-1 for Steel Boiler Plate which is] [or 55,000 lb per sq in. for all steel plates, except for special grades having a lower tensile strength.]

PAR. P-15. Revised:

P-15. *Crushing Strength of Steel Plate.*

The resistance to crushing of steel plate [shall be taken at 95,000 lb] per square inch of cross-sectional area SHALL BE TAKEN AS FOLLOWS:

| MATERIAL | SPEC. NUMBER | CRUSHING STRENGTH |
|---|---|---|
| FLANGE AND FIREBOX... | S-1, S-26, S-27, | 95,000 |
| ALLOY STEEL. | S-28, GRADE A, | 120,000 |
| | GRADE B | |

PAR. P-16. Add the following to tabular matter:

| | |
|---|---|
| ALLOY STEEL, SPECIFICATIONS S-28, GRADE A SINGLE SHEAR..... | 60,000 |
| ALLOY STEEL, SPECIFICATIONS S-28, GRADE A DOUBLE SHEAR..... | 120,000 |

PAR. P-102*e*. Add the following note to the second section:

(THE TENSION TEST OF THE JOINT SPECIMEN AS SPECIFIED HEREIN IS INTENDED AS A TEST OF THE WELDED JOINT AND NOT OF THE PLATE.)

PARS. P-102*i* and U-68*i*. Add the following to first sections:

THE JOINTS SHALL BE STRESS RELIEVED AND THEN RADIOGRAPHED WHEN THE THICKNESS OF THE METAL DEPOSITED IN THE WELD IS $4^1/_4$ IN. THE JOINTS SHALL ALSO BE STRESS RELIEVED AFTER THE COMPLETION OF THE WELDED JOINT.

PAR. P-104. First section, and Par. U-72*c*. Revised:

If the thickness of the flange of a head to be attached to a cylindrical shell by a butt joint exceeds the shell thickness by more than 25 per cent (maximum $^1/_4$ in.), the flange thickness shall be reduced at the abutting edges EITHER ON THE INSIDE OR THE OUTSIDE, OR BOTH, as shown in Fig. P-6 (U-18*a*).

PAR. P-258. Revised last sentence:

A handhole, INSPECTION OR WASHOUT opening in a shell or UNSTAYED HEAD [of a boiler drum in which the dimension in the longitudinal direction exceeds the allowable size of an unreinforced opening given in Par. P-268*a*, or in which the greatest dimension exceeds 6 in.,] shall be DESIGNED [reinforced] in accordance with the rules GIVEN in Par. P-268*b*.

PAR. P-260. Add the following:

MANHOLE FRAMES MAY ALSO BE ATTACHED BY WELDING PROVIDED THE REQUIREMENTS OF PARS. P-101 TO P-111, INCLUSIVE, OMITTING THE X-RAYING, AND PAR. P-268 ARE MET.

PARS. P-268*d* and U-59*v*. Add the following as new sections:

*d* (*v*) IF THE UNIT TENSILE STRENGTH OF ANY MATERIAL USED FOR REINFORCEMENT IS NOT EQUAL AT LEAST TO THAT OF THE VESSEL WALL TO BE REINFORCED, ADDITIONAL REINFORCEMENT SHALL BE ADDED TO COMPENSATE FOR THE LOWER TENSILE STRENGTH.

PAR. P-278. Revised second sentence:

In the case of fire-tube boilers, the openings in the boilers for safety valves AND THE OUTLET OPENING OR OPENINGS OF ANY INTERVENING FITTINGS shall not be less than given in Table P-15 for capacities determined in accordance with Par. P-274.

PAR. P-288*a*. Insert the following as second sentence:

IF THE SUPERHEATER OUTLET HEADER HAS A FULL, FREE, STEAM PASSAGE FROM END TO END AND IS SO CONSTRUCTED THAT STEAM IS SUPPLIED TO IT AT PRACTICALLY EQUAL INTERVALS THROUGHOUT ITS LENGTH SO THAT THERE IS A UNIFORM FLOW OF STEAM THROUGH THE SUPERHEATER TUBES AND THE HEADER, THE SAFETY VALVE, OR VALVES, MAY BE LOCATED ANYWHERE IN THE LENGTH OF THE HEADER.

PAR. P-299. Add the following to fifth section:

IT IS RECOMMENDED THAT CAST-IRON VALVES AND FITTINGS BE NOT USED FOR THIS SERVICE FOR PRESSURES OVER 200 LB PER SQ IN., UNLESS THE FLANGE AND BODY THICKNESSES ARE INCREASED TO MAINTAIN THE SAME DEFLECTION LIMITS AND TO GIVE AT LEAST THE SAME FACTOR OF SAFETY AS SPECIFIED FOR THE 250 LB STANDARD, IN WHICH CASE SUCH STRENGTHENED VALVES OR FITTINGS MAY BE USED UP TO 250 LB MAXIMUM ALLOWABLE WORKING PRESSURE. STEEL VALVES AND FITTINGS MAY BE STRENGTHENED FOR USE AT PRESSURES EXCEEDING THEIR NOMINAL RATING BY INCREASING THE FLANGE AND BODY THICKNESSES TO MAINTAIN THE SAME DEFLECTION LIMITS AND TO GIVE THE SAME FACTOR OF SAFETY AS SPECIFIED FOR THE NEAREST STANDARD-PRESSURE RATING.

PAR. P-307. Revised last sentence:

A properly designed [brass or] steel bushing, similar to or equivalent of those shown in Fig. P-30, or a flanged connection, shall be used.

PAR. P-325. Designate the first sentence as (*a*), the remainder of the paragraph as (*b*), and add a new section (*c*) as follows:

*c* LUGS, HANGERS, OR BRACKETS OF THE SAME SIZE AS REQUIRED FOR RIVETING AND MADE OF MATERIALS IN ACCORDANCE WITH THE CODE REQUIREMENTS MAY BE ATTACHED BY FUSION WELDING PROVIDED THE WELDING MEETS THE REQUIREMENTS OF PARS. P-101 TO P-111, INCLUSIVE, INCLUDING STRESS RELIEVING BUT OMITTING RADIOGRAPHIC EXAMINATION, AND PROVIDED THEY ARE ATTACHED BY FILLET WELDS ALONG THE ENTIRE PERIPHERY OR CONTACT EDGES, OF THE SIZE AND FORM SHOWN IN SKETCHES 1 TO 4, INCLUSIVE, IN FIG. P-7 IN WHICH $t_n$ REPRESENTS THE SHELL THICKNESS. THE STRESSES COMPUTED BY DIVIDING THE TOTAL LOAD ON THE LUG, HANGER, OR BRACKET BY THE MINIMUM CROSS-SECTIONAL AREA OF THE WELD SHALL NOT EXCEED, FOR TENSION AND COMPRESSION 40 PER CENT, AND FOR SHEAR 32 PER CENT OF THE STRESS VALUES GIVEN IN TABLE P-8 MULTIPLIED BY THE WELDED-JOINT EFFICIENCY.

PARS. P-332, L-82, H-68 and H-120, M-20 and U-66. Cancel proposed addition published in the February issue of MECHANICAL ENGINEERING and substitute the following:

PERMISSION TO USE THE SYMBOL DESIGNATED IN THE FOREGOING PARAGRAPH WILL BE GRANTED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS TO ANY MANUFACTURER COMPLYING WITH THE PROVISIONS OF THIS CODE WHO WILL AGREE UPON FORMS ISSUED BY THE SOCIETY THAT ANY VESSEL TO WHICH THE SYMBOL IS APPLIED WILL BE CONSTRUCTED IN FULL ACCORDANCE WITH THE CODE REQUIREMENTS AND THAT HE WILL NOT MISUSE OR ALLOW OTHERS TO USE THE STAMP BY WHICH THE SYMBOL IS APPLIED. A STEEL stamp[s] for APPLYING the [official] symbol [shown in Fig. P-33] MAY BE PURCHASED BY SUCH MANUFACTURER [are obtainable] from the [American] Society [of Mechanical Engineers.]

SPECIFICATIONS S-15. Insert the following as Par. 2:

2 CASTINGS SHALL BE FREE FROM PRIMARY GRAPHITE.

SPECIFICATIONS S-17, PAR. 17. Revised:

17 *Marking. A* The name or brand of the manufacturer, the grade of material from which it is made, whether SEAMLESS OR lap-welded, AND WHETHER steel or iron, TOGETHER WITH [and] the hydrostatic pressure in pounds at which it was tested, shall be legibly stenciled on each tube $1^1/_4$ IN. IN OUTSIDE DIAMETER AND OVER, PROVIDED THE LENGTH IS NOT UNDER 3 FT.

*B* ON TUBES LESS THAN $1^1/_4$ IN. IN DIAMETER AND ON ALL TUBES UNDER 3 FT IN LENGTH, THE NAME OR INITIALS OR BRAND OF THE MANUFACTURER SHALL BE LEGIBLY STENCILED OR INDICATED ON A STICKER APPLIED ON EACH TUBE.

# REVIEWS OF BOOKS

*And Notes on Books Received in the Engineering Societies Library*

## The Internal-Combustion Engine

THE INTERNAL-COMBUSTION ENGINE. Vol. 2, The Aero Engine, by D. R. Pye, with a chapter on The Aeroplane and Its Power Plant, by W. S. Farren. Oxford University Press, New York, 1934. Cloth, 6 × 9¼ in., 398 pp., 145 figs., $7.

REVIEWED BY C. FAYETTE TAYLOR[1]

THIS is the second volume in the series so ably initiated by "The Internal-Combustion Engine" by the same author (see MECHANICAL ENGINEERING, January, 1933, p. 67). It is a sound theoretical treatment of several aspects of the aeronautical engine, together with a rather extensive summary of important research, particularly in the fields of performance, lubrication, cooling and heat transfer, supercharging, and the two-stroke cycle. Considerable knowledge is presupposed in the field of the internal-combustion engine in general, and of the aero engine in particular, descriptive matter having been scrupulously avoided except where it is used to illustrate principles. This reviewer is disappointed, however, at the omission of much material which would be of help to the designer. For example, there is no fundamental consideration of engine form and arrangement, nor any discussion of the problem of using materials in the most economical way. Nothing appears in regard to internal forces, balance, or to the stresses in complex shapes in the light of recent important research. Nor is there any treatment of the increasingly important problems centering about vibration and fatigue failure.

It appears, also, that much material is included of a nature so general that it might better have been placed in the first volume. Examples of this are the protracted discussion of the chemical structure of lubricating oils, and much of the fundamental material on heat transfer. One must commend Mr. Pye on his able discussion of the two-stroke cycle in Chapter 11, which sets forth advantages and limitations in a decisive manner.

[1] Professor of Automotive Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

## The Art of Leadership

THE ART OF LEADERSHIP. By Ordway Tead. Whittlesey House, McGraw-Hill Book Company, Inc., New York, 1935. Cloth, 6 × 9 in., 308 pp., $2.50.

REVIEWED BY ROBERT I. REES[2]

INTENT reading of a book for purposes of review places upon the reader a responsibility for judgment which is sometimes difficult to meet. In the vast field of leadership there are many who seek constructive help in all the perplexities which surround their action. All are seeking a sound philosophy as a foundation for this leader-follower relationship. Does Ordway Tead's book build these sure foundations? It is believed that it does.

An intensive student of human relations and a keen observer, Mr. Tead has approached the subject of the art of leadership with originality and force. As indicated in his preface, his purpose is to set forth the meaning and methods of leadership, as contrasted with the concept and methods of command which have so long prevailed in organized human affairs. The organization of his material is excellent and is so presented that the reader is led to read himself into the situations. The leader's objectives must tend always toward a worthy purpose and set a goal which his followers find desirable. The qualities necessary in leaders are defined in their personal sense. Assuming technical proficiency, he lays great stress upon a sense of purpose and direction, enthusiasm, decisiveness, integrity, and without apology, emphasizes friendliness and affection toward the followers. One gets the impression throughout all he has written that leadership is, after all, an educational process, bent on promoting efficiency, harmony, and security through understanding.

Without overemphasis, he develops some of the techniques in this learning process. The problems of women leaders are dealt with sympathetically in a separate chapter. With frank acceptance of some of her limitations, he nevertheless pays high tribute to her fine qualities: "To every leader's capacity to energize and focus purposefulness, she peculiarly has the chance to add the exercise of her power of personal interest and human understanding, of her natural directness of individual approach and affection."

One of the strong chapters of the book is "The Leader's Deeper Resources." With the reticence of a layman and yet with fervor, he calls upon the leader to have faith and a firm conviction that effort is worth while. He should believe in some meaning in human living, in some fruitful outcome of human effort, in some sense that mankind struggles, not against, but essentially in harmony with the animating power of the universe. He makes clear that this demand for a spiritual faith has always been realized by the greatest leaders. He finally makes the point that in a democratic society we must have democratic leadership, not autocratic control, not drive, but guidance, always inviting people away from stagnation and compliance in the direction of selfhood, vision, and adjustment. There is no question that all persons having responsibility for leadership will read this book with profit.

[2] Assistant Vice-President, American Telephone & Telegraph Co., New York, N. Y. Mem. A.S.M.E.

## Engineering Education

REPORT OF THE INVESTIGATION OF ENGINEERING EDUCATION, 1923–1929. Vol. 2. Published by the Society for the Promotion of Engineering Education, Pittsburgh, Pa., 1934. Cloth, 6 × 9 in., 283 pp., 30 figs., $3 to non-members of S.P.E.E.

REVIEWED BY R. L. SACKETT[3]

IN THE October, 1930, issue of MECHANICAL ENGINEERING there was a review of Volume 1 of the Investigation of Engineering Education. That sketch recorded the initiation under the presidency of Prof. D. C. Jackson of an investigation of engineering education by Dr. C. R. Mann. In 1922 Prof. C. F. Scott, then president of the S.P.E.E., instituted the notable self-analysis, financed by the Carnegie Foundation for the Advancement of Teaching, contributions from industries, and the aid of the engi-

[3] Dean of Engineering, Pennsylvania State College, State College, Pa. Mem. A.S.M.E.

neering societies, including the A.S.M.E. This was the first time that the profession had exhibited an organized interest in engineering education.

The review mentioned inadequately such topics as the student, the teacher, the curricula, and compared technical education in Europe and the United States.

Volume 2 represents the concluding report of the S.P.E.E. investigation and contains:

(*a*) The report of Director Wickenden.

(*b*) A report on Summer Schools for Engineering Teachers, by Prof. H. P. Hammond, director of the schools.

(*c*) A report on the conference of administrative officers of engineering colleges.

(*d*) The 1930 resurvey of engineering education.

(*e*) The final report of the Board of Investigation, by C. F. Scott.

(*f*) An impressive list of S.P.E.E. publications on the investigation.

(*g*) A complete index of Vol. 1 and Part 1 of Vol. 2.

(*h*) Part 2 of Vol. 2, a study of technical institutes which is also followed by an index.

Two valuable indexes and two tables of contents covering all items of the investigation. *Selah!*

Since there are more than 1300 pages in the two volumes devoted to the investigation initiated by the S.P.E.E. in 1922 and 271 pages in the study of technical institutes, one is once more impressed with the monumental character of the work done.

The final report by Dr. Wickenden is of special value because it comes after about twelve years of investigation, experience with summer schools for engineering teachers, a resurvey made under the presidency of Col. R. I. Rees in 1930, the study of technical institutes, and the economic disturbance which has had its repercussions on education and must have given the director much food for thought. But the convulsion in business has not shaken the director's faith in the security of the foundation of engineering education.

The changing social premises of engineering education (p. 1048 et seq.) is a keen evaluation of forces applied to the superstructure and should be ruminated by teachers and engineers concerned with the future of the profession. Its implications are clear. "The social changes sketched above point inevitably to an increasing degree of social control in economic processes. The engineer of a generation hence . . . ." Read it and ponder!

"The evidence at hand indicates that engineering callings at the several educational levels are no more overcrowded than other callings at the same levels." (p. 1081.) This quotation and the one in the preceding paragraph are not quite fair to the author as the context should be read to obtain the reasoning and the inferences. The literary form and language throughout the volume are of a high order of excellence.

The 1930 review of engineering education was a happy thought and the report gives new, significant data and suggests comparisons of conditions and ideas in 1930 with those of 1923.

The report on summer schools for engineering teachers, 1927–1933, by the director, Prof. H. P. Hammond, describes the inception, the conception, plan, organization and in conclusion modestly quotes from MECHANICAL ENGINEERING to answer the question "What did the school accomplish?" More than can be put in words because much was of the spirit and intangible.

The final report of Dr. C. F. Scott, the chairman of the Board, sketches the history of the investigation, the subject matter of curricula, graduate work, the cooperation plan, the teacher, and the multiplicity of other factors included. Dr. Scott, as president in 1921–1922, and 1922–1923, organized the investigation and helped to obtain financial support for it. He did a monumental work in inspiring, directing, and energizing a study of enduring value.

The study of technical institutes will impress the unprejudiced with the absence in the United States of completely coordinated and adequate levels and kinds of technical instruction. The problem is complex, but "The Technical Institutes of Europe" gives us suggestions and cause for reflection on our industrial needs and supplies evidence of the gaps in our provision for the studied adaptation of youth to our civilization.

The two volumes constitute a cyclopedia on engineering education as revealed by a wisely directed self-analysis which is unexcelled in its thoroughness and judiciousness. It is a lamp to light the way when one is trying to see more clearly the objectives of technical education and the way of life which is called engineering.

To the teacher, one of the heartening results of the investigation is the participation of the professional engineering societies in the prosecution of this enterprise. Not only financial and moral support but personal participation was a valuable asset because it demonstrated the common interest of educators and practitioners in the broad foundation of technical education as well as in its more distinctive and professional disciplines so far as they are pursued in undergraduate instruction and as they emerge more clearly in graduate study and research.

It seems clear that the societies have become more conscious of the interrelations of education and professional progress and welfare at the same time that they have been and are most sensitive to and considerate of the relative responsibilities involved. Is it too much to say that this cooperation between the practicing and teaching professions in engineering has been profitable to both?

The Engineers' Council for Professional Development, which is a product of seven engineering societies, is, in my judgment, engaged in the most ambitious educational program fostered by engineers anywhere or at any time.

Its four concerns are with:

(1) The selection and guidance of engineering students.

(2) Professional training for the nongraduate or the graduate following graduation.

(3) The evaluation and approval of accredited curricula of engineering schools.

(4) Professional recognition such as fitness for membership in an engineering society and licensing as a professional engineer.

The E.C.P.D. is possible because of interests aroused by the investigation, carried on by the S.P.E.E. and by economic necessity and time-forces difficult to analyze. The time had arrived and conditions urged.

The E.C.P.D. program is partly educational, partly professional, and wholly significant as an evidence of unity, solidarity and the breadth of mind of engineers. It is a vigorous attack on insularity and a commanding evidence of professional foresight. Its breadth of vision is prophetic. Its economic and social products and by-products may in time prove to be realizations of an idealism which was almost fantastic a decade ago.

The investigation builded bigger and better than it knew.

## Books Received in Library

AIR CONDITIONING SIMPLIFIED, Theory, Practice and Marketing. Edited by H. L. Alt, Domestic Engineering Co., Chicago, 1934. Cloth, 5 × 9 in., 215 pp., diagrams, charts, tables, $1. This book, compiled from articles published in *Domestic Engineering*, is intended for the heating and ventilating contractor. Section one presents the fundamental theory of air conditioning and the methods of calculation used in designing installations. The

second section describes a variety of actual installations in residences and shops. Section three discusses selling methods.

ANALYTISCHE GEOMETRIE DES RAUMES. (Sammlung Göschen 89.) By R. Haussner. Walter de Gruyter & Co., Berlin and Leipzig, 1935. Cloth, 4 × 6 in., 132 pp., diagrams, illus., 1.62 rm. A concise, simple presentation of the elements of the subject.

CARE AND REPAIR OF FRACTIONAL-HORSEPOWER MOTORS. By A. G. Smith. International Textbook Co., Scranton, Pa., 1933. Leather, 5 × 8 in., 126 pp., diagrams, charts, $1.10. A manual of practical information for the electrician. Each main type and design of fractional-horsepower motor is described briefly, windings are explained, and directions given for the usual mechanical and electrical adjustments.

DAMPFTURBINEN - VERBRAUCHSDIAGRAMME, Grundlagen und Entwurf nebst Beispielen. By H. Hiedl. Julius Springer, Vienna, 1935. Paper, 6 × 10 in., 83 pp., diagrams, charts, 8 rm. As power plants usually must operate under varying loads, the behavior of prime movers when underloaded or overloaded is of interest to the designer. This book discusses the behavior of various types of steam turbines under these conditions and presents a method for plotting a diagram of steam consumption over the normal working range, by means of which the designer may arrive at an economical plan.

DAUERBIEGEFESTIGKEIT VON KONSTRUKTIONSTEILEN AN EINSPANNUNGEN, NABENSITZEN UND ÄHNLICHEN KRAFTANGRIFFSTELLEN. (Mitteilungen der Materialprüfungsanstalt an der Technischen Hochschule, Darmstadt, Heft 5.) By A. Thum and F. Wunderlich. V.D.I. Verlag, Berlin, 1934. Paper, 6 × 9 in., 82 pp., illus., diagrams, charts, tables, 7.50 rm. The fractures of axles at wheel and pulley hubs, of airplane propellers at the hub, and similar cases where a bar is confined at one end and subjected to bending forces at the other are investigated, in the light of modern knowledge of fatigue. The causes of fractures at the point of support are considered and recommendations given to guide the machine designer.

DIESEL-ENGINE DESIGN. By H. F. Shepherd. John Wiley & Sons, New York, 1935. Cloth, 6 × 9 in., 227 pp., illus., diagrams, charts, tables, $3.50. This book gives practical, detailed directions for the design of Diesel-engine parts. The author avoids extended theoretical discussions and advanced mathematics. The merits and useful ranges of other engines, as opposed to the Diesel type, are presented.

FLACHGLAS. (Das Glas in Einzeldarstellungen, Bd. 8.) By W. König, L. v. Reis, and R. Simon; edited by M. Pirani and K. Quasebart. Akademische Verlagsgesellschaft, Leipzig, 1934. Paper, 6 × 9 in., 174 pp., illus., diagrams, charts, tables, 11 rm. Current practice in drawing and rolling glass and the various machines and processes used are described concisely in this work, which is one of a series covering the glass industry. The processes cover the manufacture of window glass, plate glass, wire and ribbed glass, etc. The work is written from a practical point of view.

FORSCHUNGSHEFT 369. BEANSPRUCHUNG IN GELOCHTEN PLATTEN. By E. Siebel and E. Kopf. V.D.I. Verlag, Berlin, 1934. Paper, 8 × 12 in., 22 pp., illus., diagrams, charts, tables, 5 rm. This report describes an investigation of the distribution of stresses in plates perforated with several holes. Measurements were made under varied conditions, with special attention to those found in water-tube boilers. The methods used and the experimental findings are described, with suggestions for their practical use in boiler design.

GREAT BRITAIN. AERONAUTICAL RESEARCH COMMITTEE, Report for the Year 1933–1934. His Majesty's Stationery Office, London (obtainable from British Library of Information, N. Y.), 1934. Paper, 6 × 10 in., 89 pp., illus., 1s 6d, $0.50. The report contains a full account of the technical work carried on during the year by the various sub-committees on aerodynamics, fluid motion, structures, engines, alloys, etc.

GREAT BRITAIN. Department of Scientific and Industrial Research. Report of the Committee on the MECHANICAL TESTING OF TIMBER. His Majesty's Stationery Office, London (obtainable from British Library of Information, N. Y.), 1934. Paper, 6 × 10 in., 41 pp., illus., diagrams, charts, 1s, $0.35. This committee, under the chairmanship of Sir Alfred Ewing, was charged with a review of the testing of timber for strength and elasticity. It has examined critically the methods used in the Forest-Products Research Laboratory, and the tests prescribed in the British Standard Specifications, which are in the main those of the American Society for Testing Materials. The report summarizes the work of the committee and gives its conclusions as to the value of the different tests.

GREAT BRITAIN. Department of Scientific and Industrial Research. Report of the FOREST PRODUCTS RESEARCH BOARD, 1933. His Majesty's Stationery Office, London (obtainable from British Library of Information, N. Y.), 1934. Paper, 6 × 10 in., 67 pp., illus., charts, maps, 1s 3d, $0.45. The most interesting part of this pamphlet is the concise summary of the investigations which were in progress during 1933 at the Forest-Products Research Laboratory. These were concerned with a great variety of matters of scientific and industrial interest, such as methods of seasoning timber, timber preservatives, the chemistry of decay, insect damage, etc.

IDENTIFICATION OF FIREARMS from Ammunition Fired Therein with an Analysis of Legal Authorities. By J. D. Gunther and C. O. Gunther. John Wiley & Sons, New York, 1935. Cloth, 6 × 9 in., 342 pp., illus., tables, diagrams, $4. This book deals with an important subject, the identification of firearms as related to the judicial process, and combines in one volume a study of both the scientific and the legal aspects of the subject. The principles of firearms identification from ammunition fired therein are explained clearly, and the methods used by the scientific expert are described. For the lawyer, it provides an analysis of cases which involved the identification of firearms and discusses critically the evidence submitted. It also suggests proper methods of handling such evidence and of examining witnesses.

MACHINE DESIGN, 3 Vols. By M. E. Steczynski. International Textbook Co., Scranton, Pa., 1933. Leather, 5 × 8 in., illus., diagrams charts, tables; vol. 1, 130 pp., $1.25; vol. 2, 154 pp., $1.50; vol. 3, 160 pp., $1.75. These three volumes provide an elementary course in practical machine design, intended primarily for home study. Only elementary mathematics is used, and theoretical discussions are omitted. The book should be useful to the young engineer as a practical guide.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN GHH-KONZERN, vol. 3, part 6, December, 1934. Paper, 8 × 12 in., p. 141–170, Berlin, V.D.I. Verlag, illus., diagrams, charts, tables, 3.40 rm. This number contains three articles: Modern Ship Forms, by Dr. W. Scholz; The Damping of the Vibrations of Internal-Combustion Engines, by Dr. J. Geiger; A Speed Governor for Steam Hoisting Engines, by W. Schuermann.

NITROCELLULOSE ESTER LACQUERS, Their Composition, Application and Uses. By F. Zimmer; translated by H. K. Cameron. D. Van Nostrand Co., New York, 1934. Cloth, 6 × 9 in., 246 pp., illus., diagrams, tables, $7. The composition, application, and uses of these lacquers are described by a well-known German chemist, long associated with the industry. The treatment is essentially practical and the accounts of raw materials, manufacturing methods, testing and analysis, and methods of lacquering are concise and informative.

ORGANIC CHEMISTRY OR CHEMISTRY OF THE CARBON COMPOUNDS. VOL. 1, CHEMISTRY OF THE ALIPHATIC SERIES. By Victor von Richter; translated and revised from the twelfth German edition by E. N. Allott. Kegan Paul, Trench, Trubner & Co., Ltd., London; P. Blakiston's Son & Co., Philadelphia, 1934. Cloth, 6 × 9 in., 790 pp., diagrams, tables, $10. The new edition of this well-known textbook incorporates the new and revised matter of the twelfth German edition, with further additions. Volume one deals with the aliphatic series. The work is a comprehensive advanced text, most useful for reference use, and has long been a favorite of advanced students, who will welcome this revision.

ORES AND INDUSTRY IN SOUTH AMERICA. By H. Foster Bain and T. T. Read. Published for the Council on Foreign Relations by Harper & Brothers, New York and London, 1934. Cloth, 6 × 9 in., 381 pp., tables, cloth, $3.50. The purpose of this work is to explain just what the mineral resources of South America are, where they are situated, what part they have played in the history and development of each country, and to estimate the part they may be expected to play in the future. The authors have brought to the task personal experience in many parts of the continent, as well as wide familiarity with the literature, and have prepared a comprehensive, accurate summary of conditions. The book will be welcomed by all interested in social, economic, and industrial conditions in South America.

RESISTANCE OF MATERIALS. By F. B. Seely. Second edition. John Wiley & Sons, New York, 1935. Cloth, 6 × 10 in., 436 pp., illus., diagrams, charts, tables, $3.75. While the purpose of this book, to provide a text for the standard college course in the subject, has been kept, the work has been revised and rearranged, and is entirely reset. Part one covers the usual undergraduate course, while part two treats briefly some special topics in stress analysis of more advanced character. In this edition special emphasis is given to the engineering significance of the subject, not merely to mathematical methods of analysis.

# WHAT'S GOING ON

## This Month's Authors

ALLAN R. CULLIMORE, member, A.S.M.E., who writes on the discussion group devoted to citizenship which Roy V. Wright conducts at the Newark College of Engineering, has been engaged in engineering education since 1912, prior to which he was employed by the American Bridge Company. He is chairman of the A.S.M.E. Committee on the Citizenship Manual. He has been president of the Newark College of Engineering since 1927.

Jerome C. Hunsaker, member, A.S.M.E., who reports on studies in cavitation at M.I.T., is well known as the designer of the airship *Shenandoah* and the flying boat *NC4*, first aircraft to fly the Atlantic, and for other contributions to aeronautics. Since 1933 he has been head of the department of mechanical engineering at the Massachusetts Institute of Technology.

Charles Murray Gratz, M.D., and Solon N. Blackberg are two non-engineers who have applied engineering methods to the study of the strength characteristics of the fibrous tissues of the bodies of animals. Dr. Gratz is in the practice of surgery and on the teaching staff of Columbia University and the Post Graduate Hospital, and on the surgical staff of the City Hospital, New York. He has devoted much time to clinical and research problems in the transplantation of tissues.

Dr. Blackberg, member of the staff of the College of Physicians and Surgeons in pharmacology since 1930, who collaborates with Dr. Gratz, has been interested in fibrous tissues because of his desire to develop a normal standard with which to compare fibrous tissues in animals and man subjected to various dietary deficiencies.

Lauren E. Seeley, member, A.S.M.E., assistant professor of mechanical engineering at the Yale School of Engineering, has been engaged in the experimental study of heating equipment since 1916. His activities have brought him recognition in technical committees of the American Society of Heating and Ventilating Engineers and in the preparation of codes for testing heating equipment. He is a consultant for the H. B. Smith Co., manufacturers of heating boilers.

C. W. MacGregor, junior, A.S.M.E., who presents this month a study of the deflection of gear teeth, studied under Dr. S. Timoshenko, and has worked at the Westinghouse Research Laboratories under Dr. A. Nadai. At present he is an instructor in applied mechanics at the Massachusetts Institute of Technology.

Harold E. Edgerton, of the electrical engineering department at the Massachusetts Institute of Technology, who contributes the "frontispiece" and a brief description of some of his stroboscopic studies, has produced many new and useful results in this field. Noteworthy among these is the development of a high-speed motion-picture camera for photographing rapidly moving objects.

Royd Ray Sayers, M.D., is medical officer in charge of industrial hygiene and sanitation of the United States Public Health Service, Washington, D. C. He has served as chief chemist of the Gould Storage Battery Co., as professor of electrochemistry at the University of Buffalo, and as the chief surgeon, U. S. Bureau of Mines. In cooperation with W. P. Yant he developed the pyrotanic-acid method for determining the carbon monoxide in the blood and air and the use of synthetic atmospheres for the prevention of caisson disease.

Joseph M. DallaValle is assistant sanitary engineer of the United States Public Health Service. Following his graduation from Harvard in 1927 he did work there in industrial hygiene and air-conditioning. In the Department of Trade Wastes, Cleveland, Ohio, he worked on the control of dusts, smokes, and fumes, with special reference to the design of air-filtration apparatus.

R. E. Freeman is acting head of the department of economics at the Massachusetts Institute of Technology. His contribution is cast in the form of a review of a book on economics written by an engineer. This is the first of a group of similar comments on current economics as it affects engineers, sponsored by the A.S.M.E. Management Division.

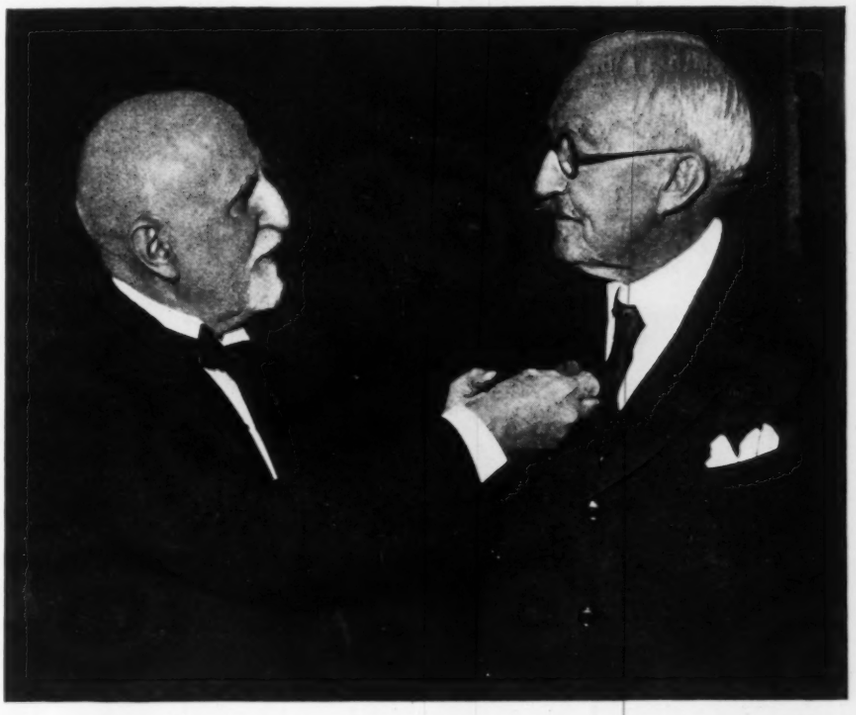
William McClellan, member, A.S.M.E., president of the Potomac Electric Company, Washington, D. C., possesses to a remarkable degree that "personality" which is so important in achieving success in the business world, and about which he has written this month.

Christopher H. Bierbaum, member, A.S.M.E., vice-president and consulting engineer, Lumen Bearing Co., Buffalo, N. Y., has written extensively on subjects relating to bearings, bearing metals, and microscopy, and holds many patents in these fields.

M. J. Hanlon, who has been operating manager and vice-president of the Black Diamond Steamship Corporation, New York, N. Y., served for six years at sea as chief engineer, and in New York, with the United States Lines.

## Mortimer E. Cooley Honored

AT A DINNER given in his honor on February 12 at the Detroit Athletic Club, Detroit, Mich., Mortimer E. Cooley, past-president, The American Society of Mechanical Engineers, dean emeritus, School of Engineering, University of Michigan, and chief engineer of PWA for the State of Michigan, was presented the A.S.M.E. Fifty-Year Medal. The Fifty-Year Medal presentation is a feature of the A.S.M.E. Annual Dinner, in New York. Dean Cooley, however, was unable to be



MR. DOW PRESENTING A.S.M.E. FIFTY-YEAR MEDAL TO DEAN COOLEY

present at this occasion and hence the presentation was made in Detroit.

About 40 members of the Society and friends of Dean Cooley, who will be 80 years old on March 28, were present at the dinner. Alex Dow, past-president, A.S.M.E., and president, Detroit Edison Company, presented the medal. The stories with which the guests were regaled were in the best Cooley manner.

The dinner was arranged by the Detroit Section, A.S.M.E., under the chairmanship of L. J. Schrenk, superintendent of the Public Lighting Commission.

## A.E.C. News

THE Work Relief Bill, after weeks of deadlock, again moves toward enactment with its $4,880,000,000 fund for projects throughout the country. Each phase of the program earmarked in the present draft of the bill is essentially an engineering job. The function of the engineer has become increasingly recognized in these works so that the expansion of technical staff, both in Washington and in the field, after the bill passes is a pre-arranged certainty. In addition, a special item of $300,000,000 goes to projects for professional and clerical people.

Who runs the program is still a question. The council has been working with some of the planners. Jobless engineers are at a disadvantage in seeking placement under the program until it is revealed just which agencies will handle the various projects. Present steps may include registration with nearest U. S. Employment Office; securing of political endorsements from county chairman upward; filing applications with Federal agencies in Washington or in field offices. Civil service examinations are a longer shot but long shots have to be taken in times like these. Inquire at your post office or write the Civil Service Commission, Washington, for lists of pending examinations.

### BUREAU OF LABOR STATISTICS SURVEY

The survey of the engineering profession, under the direction of the Bureau of Labor Statistics, is about to go forward with upward of 170,000 names compiled under the direction of the Committee on Engineering and Allied Technical Professions, with the assistance of 12 relief workers in New York. The engineering societies cooperated so well that the job was far bigger than the expected list of 100,000. The consequent delay was well worth while in extending the base of the survey. The card file of names has been sent to the Bureau of Labor Statistics and the final questionnaire was approved at a meeting at New York, March 4.

### N.B.E.R. MEETING AND REPORTS

The National Bureau of Economic Research, in whose work the A.E.C. is a cooperating agency, reported noteworthy progress and good financial condition at its annual meeting last month. Recent studies include incomes of consulting engineers, physicians, dentists, and lawyers. Tables will summarize gross and net income for each profession, the differences in towns of various sizes, and other factors. Dr. Harry Jerome's report on "Mechanization of Industry" shows the effect of the machine upon volume of employment, skill required by the workers, fatigue, health, and quality of product. A new report on public works in relation to the national economy has been prepared by Dr. Arthur D. Gayer. The report on "Strategic Factors in Business Cycles," by Prof. John Maurice Clark, suggests the strategic place of the engineer in the modern business system. Other publications relate to wage rates and working hours, recent corporate profits, and national income. Detailed information may be secured by writing the Bureau, 1819 Broadway, New York, N. Y.

### NEW MEMBERS

The Council's new membership plan has definitely brought in the Engineers Club of Philadelphia and the Engineering Societies of New England. The Engineers Society of Western Pennsylvania, Engineers Club of St. Louis, and Michigan Engineering Society have voted to recommend to their executive committees that they join. Membership is under consideration by the Louisiana Engineering Society, Illinois Engineering Society, and Cleveland Engineering Society. Interest has been manifested by several others.

### UNEMPLOYMENT STATISTICS

Estimates of unemployment of engineers have been supplied in response to a request by William Green, president of the American Federation of Labor, referred to Council by the Engineering Foundation. An arrangement is suggested whereby the A. F. of L. will note the status of engineering employment from time to time in statistical reports.

### DIRECTORY OF ENGINEERING SOCIETIES

The directory of engineering societies is ready for distribution at 50 cents per copy. It includes the names of officers, membership requirements, names of publications, and other data regarding national, state, and local societies.

## E.C.P.D. Program Described to Engineers in New York

THE Metropolitan sections of five national engineering societies, representing civil, electrical, mechanical, chemical, and mining engineers, met in New York, March 6, in the auditorium of the Engineering Societies Building to hear four eminent engineers discuss the aims and achievements of the Engineers' Council for Professional Development. The Council is a conference of engineering bodies organized to enhance the professional status of the engineer through the cooperative support of national organizations dealing with various phases of an engineer's life. Gano Dunn, president of the J. G. White Engineering Corporation, and recently elected chairman of the board of trustees of Cooper Union, presided. The speakers were C. F. Hirshfeld, chairman of the Council and chief of research of the Detroit Edison Co., R. I. Rees, chairman of the Council's committee on professional training and assistant vice-president of the American Telephone and Telegraph Co., and J. W. Barker, member of the Council's committee on professional recognition and dean of the school of engineering of Columbia University.

Referring to the apparent diversity of engineering occupations, which has followed in the wake of science and invention, Mr. Dunn emphasized the essential unity of all engineers in their methods of attacking problems. "I see in the Engineers' Council for Professional Development," he said, "the dawn of a professional self-consciousness among engineers, the effects of which on the engineer's status in society and on his satisfactions in life may be profound. The Council," he added, "rests upon and derives its strength from the whole profession."

Engineering is not wholly a development of modern civilization, according to Dr. Hirshfeld, for there have always been men who used materials and natural laws to assist them in accomplishing their ends. "In recent times," he said, "the rapid growth of our knowledge of the natural sciences has greatly accelerated engineering activity, even to the point where it is being charged with some of our economic troubles. Dr. Hirshfeld decried shallow criticism of the engineer and his works, but admitted that technological progress was only half of the engineer's job. "It is high time the engineer came out of his technological shell," he said, "and began to take an interest in the real world around him." As a step in preparing engineers to play a larger part in social and economic affairs, the Engineers' Council for Professional Development has been organized by seven national engineering groups representing the technical, social, educational, and legal aspects of the engineer's life. "The Council maintains," said the speaker, "that if the engineer makes himself a sufficiently well-trained, broad-visioned, generally capable person, recognition by the world at large is bound to occur. The engineer will be recognized in proportion to his ability to serve society broadly and not in a narrow technical sense."

### FOUR MAJOR COMMITTEES AT WORK

"The work of the Council begins with the prospective engineering student, considers the fundamentals of his technical, social, and economic training, follows him through his early post-college years, and finally examines his fitness for recognition as an engineer," according to Dr. Hirshfeld. For these purposes, he continued, "four major committees have been set up dealing, respectively, with student selection and guidance, engineering schools, professional training, and professional recognition. The product one gets out of any educational process is determined largely by the quality of the raw material. We are therefore trying to find ways of evaluating

that raw material before it undertakes the long, hard grind of an engineering education. If this can be done there should be an improvement in the average character of recruits to the engineering profession." Guidance literature and aptitude tests are among the practical measures now being used to select students for engineering courses, the speaker explained. Engineering schools are to be accredited by a committee of the Council, it was stated, not for the purpose of standardizing engineering training, but rather for the purpose of discovering weaknesses in our educational structure and improving the quality of instruction. But in spite of careful selection and education of students, much remains to be done to develop them into engineers. "Therefore," said Dr. Hirshfeld, "we shall endeavor to pick up the young graduate when he leaves college and assist him in becoming the broadly educated, well-rounded individual that we now believe is required. Finally, the Council will endeavor to set up criteria of performance and accomplishment for engineers, and give professional recognition to those who can meet a minimum standard of accomplishment."

General Rees elaborated the work of his committee on professional training after graduation. Two practical aids to the graduate have been prepared in the form of a personal appraisal blank and a reading list. "The former," said General Rees, "is designed to help the young engineer develop, on his own initiative, a sound program of post-college training after a searching personal examination of his own traits, characteristics, needs, and preferences. The latter will give him an outline for reading and study in economics, culture, and general fields of knowledge. Both of these aids will prepare him for later professional recognition as an engineer." Another phase of the committee's work, according to General Rees, is the organization of senior engineers throughout the country as consultants and advisers to younger men who are undertaking the program of professional development.

The ultimate aim of the Council, it was explained, is to establish recognized criteria for the use of the professional title of engineer. At present there are no uniform standards although many of the states have adopted a system of licensing engineers by examination. It is for the purpose of bringing some order out of the present chaotic condition that the Council proposes to serve as a central body to determine who is qualified to practice as an engineer and use the professional title. Dean Barker outlined the policy of the committee on professional recognition, explained the derivation of the minimum definition of an engineer, and the program of certification. "It is the expectation of the Council," said Dean Barker, "that a system of certification will be developed that will meet all the requirements of various bodies that now have varying standards for recognizing engineers and authorizing the use of the professional title. Thus certification by the Council might be acceptable to state boards of engineering examiners, and might also be accepted by colleges as a basis for granting the professional degree of engineer after graduation."

## A.S.M.E. Meets in Cincinnati, June 19 to 21

TAKING advantage of the opportunities offered in the machine-tool district of Cincinnati, the A.S.M.E. is devoting four of the sessions of its 1935 Semi-Annual Meeting, to be held in that city June 19 to 21, to its Machine Shop Practice Division. Machine tools will be discussed at two of these sessions; power transmission and lubrication being the subjects for the others.

Sessions sponsored by the Fuels and Steam Power Division, and by the Materials Handling, Railroad, Iron and Steel, Management, Aeronautics, and Process Industries Divisions have been planned. The Committee on Education and Training for the Industries will also present some papers.

In connection with the Graphic Arts Research Bureau and the Lithographic Research Foundation, the A.S.M.E. Graphic Arts Division will take part in the special program of the Graphic Arts Conference, to be held at the University of Cincinnati.

## Southern Textile Meeting, Greenville, S. C., April 10

THE Southern Textile Meeting under the joint auspices of the Textile Division and the Greenville Local Section of the A.S.M.E. will be held this year on Wednesday, April 10, at the Poinsett Hotel in Greenville, S. C., during the Southern Textile Exposition.

A technical session will be held in the morning with papers on "Air Conditioning in Textile Plants," by G. P. Patterson; "Disposal of Textile Wastes," by C. D. Blackwelder; and "Textile Mill Lighting," by L. W. Burdette. The afternoon will be open either for a visit to the Southern Textile Exposition or for golf at the Greenville Country Club. An informal dinner will be held at 6:30 p.m. J. R. Gill, chairman of the Greenville Section, will preside, and addresses will be given by Frederick M. Feiker and Robert M. Gates.

## News of A.S.M.E. Aeronautic Division

THE Aeronautic Division of The American Society of Mechanical Engineers will hold its annual meeting at St. Louis, Mo., in October, 1935. Major James A. Doolittle, of St. Louis, who has been elected Chairman of the Division for 1935, will have charge of arrangements for the St. Louis Meeting. Major Doolittle, who broke the cross-continent flying record in January, plans to make a tour of aircraft factories and research laboratories so as to arrange a technical program for St. Louis that will present the most outstanding features on aeronautics.

Jerome Lederer, secretary of the Aeronautic Division, announced that the New York local meeting will be held on April 24 and will be devoted to private flying. The division will have a session at the Society's Semi-Annual Meeting to be held in Cincinnati, June 19 to 21, at which blind flying and propellers will be discussed. The Division will assist local sections throughout the country in holding aeronautic meetings.

The new industrial aerodynamics committee of the division, of which Prof. Alexander Klemin is secretary, plans to stimulate the use in other industries of aerodynamic information developed by the aeronautic industry. One of the principal activities of the committee will be in the railroad field, but others such as marine and ventilation are not being neglected. The members of the committee are as follows: Alexander Klemin, Secretary, Oliver Allen, W. H. Carrier, H. E. Davison, H. P. Frear, W. G. Grove, O. E. Hovey, A. L. Kimball, R. J. S. Pigott, and L. K. Sillcox.

The Division announces the appointment of Victor J. Azbe and Clark Millikan on the "Spirit of St. Louis" Medal Board to replace P. deC. Ball and W. F. Durand.

## Applied Mechanics Division to Hold National Meeting in June

THE Applied Mechanics Division of the A.S.M.E. will hold its National Meeting at the University of Michigan, Ann Arbor, Mich., on June 18 and 19. This will precede the Semi-Annual Meeting of the Society to be held in Cincinnati, June 19 to 21, and has been arranged so that A.S.M.E. members may attend both meetings. Members of the teaching profession may then continue on to Atlanta, Ga., where the Society for the Promotion of Engineering Education will be holding its summer meeting.

The program for the Applied Mechanics meeting is being arranged by Dr. S. Timoshenko, of the University of Michigan, and the executive committee of the division. Dr. Timoshenko promises interesting lectures by celebrated foreign engineers who will be in this country at that time.

Prof. J. A. Goff, of the University of Illinois, is chairman of the executive committee. His associates on the committee are E. O. Waters, secretary, R. Eksergian, C. R. Soderberg, J. C. Hunsaker, A. L. Kimball, J. M. Lessells, and G. B. Pegram.

## A.S.M.E. Graphic Arts Division

THE Printing Industries Division of the A.S.M.E. has changed its name to the Graphic Arts Division. The change has been approved by the executive committee of the Council, since the industry has gradually accepted the term "graphic arts" as the one covering all methods of printing.

This division is arranging a program for the Semi-Annual Meeting of the Society in Cincinnati and is also planning to issue early in April the proceedings of the National Meeting held last October in Philadelphia. These proceedings will be sent to all those registered in the former Printing Industries Division.

Edward Epstean is the chairman of the Division for 1935, succeeding John Clyde

Oswald. Mr. Epstean is chairman of the board of the Walker Engraving Company, New York. Other members of the executive committee are J. M. Farrell, R. G. MacDonald, B. D. Stevens, E. P. Hulse, and J. C. Oswald. The executive committee has the following associates: V. Winfield Challenger, Summerfield Eney, Jr., F. M. Flynn, H. L. Gage, A. E. Giegengack, W. C. Glass, H. Groesbeck, Jr., W. F. Harvey, T. R. Jones, H. Ortman, H. M. Tillinghast, G. D. Bearce, W. R. Maull, W. S. Huson, and A. C. Jewett.

## A.S.M.E. Oil and Gas Power Meeting, Tulsa, May 8 to 11

THE National Oil and Gas Power Meeting will be held in Tulsa, Okla., May 8 to 11, at the Hotel Mayo, it was announced by Ralph Miller, chairman of the Oil and Gas Power Division of The American Society of Mechanical Engineers. The meeting will be held jointly with the A.S.M.E. Mid-Continent Section which will arrange the part of the program dealing with Diesel problems of the oil fields. L. H. Morrison, of New York, will have charge of arranging the other part of the technical program, which will cover developments of national interest in the Diesel field.

The usual exhibit of oil-engine parts, materials, and accessories will be held in connection with the meeting. The committee in charge of the exhibit comprises Harte Cooke, chief engineer, McIntosh and Seymour Corporation; Lester Goldsmith, consulting engineer, Atlantic Pipe Line Company; Lee Schneitter, plant betterment engineer, Electric Bond and Share Company; and J. F. Eaton, Jarecki Manufacturing Company, Tulsa, Okla.

This meeting will afford the usual opportunity for Diesel engineers and those interested in operation and design of Diesel engines to visit the Mid-Continent oil fields. The local arrangements committee, of which J. F. Eaton is chairman, is planning as part of the program several interesting inspection trips to Diesel plants in that area. This is the first time this national meeting has been held in the oil country and an excellent meeting is promised.

## Progress Reports Available in Railroad and Aeronautic Fields

THE progress report of the Railroad Division of the A.S.M.E. for 1934, prepared by George W. Rink, and presented at the 1934 Annual Meeting of the Society, has been mimeographed and sent to those registered in the Railroad Division. Others desiring copies may secure them upon request.

The progress report of the Aeronautic Division consisting of five sections dealing with aerodynamics, aircraft power plants, airplane design and construction, meteorology progress, and Army aircraft progress is also available for distribution on request. The sixth section on "Progress in Naval Avaition" was published in the October, 1934, issue of MECHANICAL ENGINEERING.

## A.S.M.E. Process Industries Division Appointments

THE A.S.M.E. Process Industries Division which was formed a year ago, has now appointed twelve subcommittees, the most active of which are heat transfer, air-conditioning, and drying. Other subcommittees are as follows: Cotton-seed processing, pulverizing, sugar, sanitation, unit-operation costs, ceramics, breweries, food processing, and paper and pulp. The new chairman is Victor Wichum, who replaces C. E. Harrington, of Buffalo, who organized the division. T. R. Olive is secretary. John H. Sengstaken is chairman of the Heat Transfer Committee which is planning sessions on radiation heat transfer at the 1935 A.S.M.E. Annual Meeting.

## Ernest Hartford, Assistant Secretary, A.S.M.E., to Visit South

VISITS to the A.S.M.E. Local Sections and Student Branches in the South will be made by Ernest Hartford, assistant secretary of the A.S.M.E., during April. He will speak on the subject "The New Era in the Engineering Profession." His itinerary follows:

April 1, Birmingham, Ala.
April 2, Atlanta, and Georgia School of Technology
April 4, Florida Section and University of Florida
April 8, Savannah, Ga.
April 9, Charlotte, N. C.
April 10, Greenville, S. C.
April 11, Greensboro, N. C., University of North Carolina, Raleigh, and North Carolina State College
April 12, Virginia Section (at Petersburg)

## Coming Meetings of A.S.M.E. Local Sections

*Florida:* April 4–6. Joint meeting with the Florida Engineering Society at the Miami Biltmore Hotel, Miami, Florida. Subject: The Results of Research in Feedwater Control, by E. W. Nick, President, Northern Equipment Co., Erie, Pa.; Metal Spraying, by William M. Kennedy, President, Condenser Service & Engineering Co., Hoboken, N. J.; Value and Application of Refrigeration to Florida, by L. W. Culter, Florida Power & Light Co., Miami, Florida; Air Conditioning in Railway Coaches, by Edward S. Roth, senior mechanical engineering student, University of Florida.

*Houston:* April 9. Houston Lighting & Power Co., Assembly Room, at 7:30 p.m. Subject: Air Conditioning, by Walter E. Becker, Regional Manager, York Ice Machinery Corp.

*Kansas City:* April 19. Meet at main entrance of Corn Products Plant, at 8:00 p.m. Inspection trip through plant, North Kansas City, Mo.

*Louisville:* April 5. Engineers' Club, Norton Building, Louisville, Ky., at 8:00 p.m. Joint meeting with the N.A.P.E. Subject: Modern Water Purification, by Mr. Bready, Representative of the Permutit Co., New York, N. Y.

*Mid-Continent:* May 8-11. Tulsa, Okla., National Meeting of the Oil & Gas Division of the A.S.M.E.

*Milwaukee:* April 18. Wisconsin Club at 8:00 p.m. Subject: The Engineer and Social Well Being, by Ralph E. Flanders, President of the A.S.M.E., and President of the Jones & Lamson Machine Company of Springfield, Vt.

*Philadelphia:* April 23. Philadelphia Engineers Club, 1317 Spruce St., Philadelphia, Pa., at 8:00 p.m. Subject: Industry in National Defense, by B. E. Kirk.

*Schenectady:* April 18. Edison Club, Schenectady, N. Y., at 8:00 p.m. Subject: Engineering Features of Schenectady Mercury-Vapor Power Plant.

*Toledo:* April 25. Motion Pictures of the Pan-American Airways Lindbergh trail will be shown.

## Engineering Index, Inc., to Appeal to Industry for Funds

ENGINEERING INDEX, INC., will appeal to the nation's industry operating in technical fields for a working capital fund of approximately $160,000 with which to continue the service and spread its use throughout the engineering offices, libraries, and colleges of the country, over a five-year period, after which it is estimated it will be self-sustaining. This project has just been announced by Collins P. Bliss, Dean of the College of Engineering at New York University and President of the Board of Directors of the Index.

At the annual meeting of The American Society of Mechanical Engineers in 1933 it was voted to discontinue the Society's responsibility for, and financial losses accruing from, the operation of the Index. This decision became effective the beginning of 1934. In June, 1934, the Index was formally incorporated as a non-profit organization in its own right. This followed an extensive study by an outside organization which developed the following conclusions:

(1) The Engineering Index service is unique in its field and, for scientific purposes, is not duplicated by any other indexing and abstracting service.

(2) If it were not for the Index, the engineering field would be the only major field of scientific knowledge without a complete and effective organization of its current literature.

Precedent for a campaign in industry for the Index is found in the raising of money for cooperative industrial research, of which there has been an increasing amount, even during the depression. The index is an important if not vital aid to industrial research and is widely used in that capacity.

The study last spring included a cross-section of opinion in the profession, obtained through personal interviews with representative engineers in New York, Philadelphia, Boston, Detroit, and Chicago. The majority opinion was that the Index should by all means

(*Continued on page 270*)

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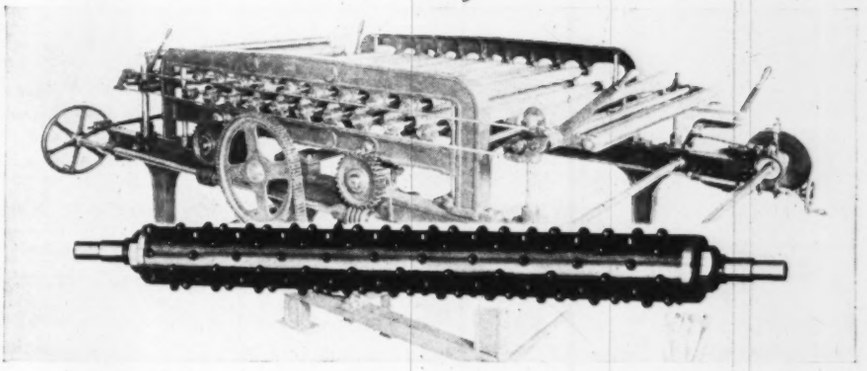

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be preserved. The majority opinion was, further, that the responsibility for saving the Index, by giving it a capital fund with which to operate, rested upon industry.

The present board of directors includes, besides Dean Bliss, Harold V. Coes, manager, industrial department, Ford, Bacon, and Davis; Ralph E. Flanders, president, Jones and Lamson Machine Company; Robert M. Gates, vice-president, Combustion Engineering Company, Inc.; and Clarence F. Hirshfeld, chief of the research department, Detroit Edison Company.

The charter of the Index, which describes the typical membership, non-profit corporation under the New York State law, provides for 50 trustee members who, Dean Bliss says, are to represent all the important engineering bodies in the country. Enlistment of this group has only begun, but now includes Mr. Flanders, President, The American Society of Mechanical Engineers, to represent that Society; Miss Granville Meixell, Librarian of Applied Science Library at Columbia University, to represent the Special Libraries' Association; C. L. Warwick, secretary-treasurer, American Society for Testing Materials; and Lester C. Morrow, editor, *Factory Management and Maintenance* as a representative at large.

The plans for the campaign call for a National Campaign Committee, and local committees for each of twelve industrial centers. National committee headquarters have been established in suite 1716–18 of the National Association Building, 25 West 43rd St., New York, N. Y. Frank B. Jewett, president, Bell Telephone Laboratories, Inc., has accepted the chairmanship of the National Committee.

## Engineering Mechanics Summer Session at Michigan

A SERIES of courses in advanced mechanics will be given at the University of Michigan during the summer of 1935. The courses are especially planned for teachers of engineering mechanics and graduates working for the doctor's degree in this subject. The courses include the following:

Theory of Elasticity for Engineers. Prof. R. V. Southwell, Oxford University, England.

Theory of Vibration With Application in Engineering. Prof. S. Timoshenko, University of Michigan.

History of Mechanics. Professor Timoshenko.

Theory of Thin Plates and Shells. E. L. Eriksen.

Advanced Theory of Structures. L. C. Maugh.

Aerodynamics. M. J. Thompson.

Courses with which laboratory work will be given are as follows:

Modern Development in Fatigue Testing of Materials. F. L. Everett.

Photoelastic Methods of Stress Analysis. E. E. Weibel.

A seminar in engineering mechanics will accompany the courses, directed by Professors Southwell and Timoshenko. Several prominent professors and engineers have promised to participate.

Communications regarding the course may be directed to Prof. S. Timoshenko, University of Michigan, Ann Arbor, Mich.

## Wanted—A Name

A COMMITTEE appointed by Harvey N. Davis, president, Stevens Institute of Technology, under the authority of the 1934 Steam Table Conference, is considering an appropriate name for the thermodynamic function that the steam tables call "heat content" or "total heat." Prof. F. O. Ellenwood, of Cornell University, is chairman of the committee. Serving with Professor Ellenwood are W. A. Carter, the Detroit Edison Company; J. A. Goff, University of Illinois; P. H. Hardie, Brooklyn Edison Company; J. H. Keenan, Massachusetts Institute of Technology; R. P. Kolb, North Carolina State College; L. C. Lichty, Yale University; W. H. Martin, Oregon State Agricultural College; R. F. Raber, University of California; J. C. Smallwood, The Johns Hopkins University; and Milton C. Stuart, Lehigh University.

The committee desires suggestions, which may be sent to the chairman, or to any of its members.

## Engineering Societies Library Extensively Used

IN THE 1934 report of the Engineering Societies Library Board, the Director, Harrison W. Craver, says:

It is gratifying in view of the scattered membership of the Founder Societies to call attention to the use that distant members make of the library. Of those using it in 1934, 26 per cent were non-visitors, served by telephone or correspondence. This proportion of one in four is greater, it is believed, than in any comparable library. It shows that this is not a local institution, of benefit only to those in its immediate vicinity.

The library was used by 40,789 persons during 1934. Of these 29,928 were readers, and 10,861 were non-visitors who consulted the collection by correspondence. The corresponding figures for 1933 were 32,258 and 10,657. Sixty-eight searches and 109 translations were supplied and 143 books were lent to 127 members. Photoprint orders from 2366 persons required the making of 18,493 photographs. Assistance was given to 2907 persons by letter and to 5284 by telephone.

The use varies little from that in 1933 when 42,915 persons were served. The Service Bureau was used by 2543 persons, an increase of eight per cent over 1933.

Advertisements and articles published in the various society journals during the year have brought many requests for advice and assistance.

### ACQUISITIONS

Total acquisitions of books, maps, pamphlets, etc., amounted to 10,410 items, a small increase over 1933. Of these, 1243 were purchased, the remainder being presented by members of the Founder Societies, publishers, and other friends. On January 1, the book collection comprised 131,793 volumes, 6847 maps, 4220 searches, and 800 pamphlets. The loan collection on December 31, contained 782 volumes, and the duplicate collection approximately 11,000 volumes.

During the year 2821 volumes, representing 2843 titles were cataloged. Of the 145,620 volumes, maps, etc., on hand, 145,285 are fully cataloged, and the remainder are in process.

### PERIODICAL INDEX

The current index to periodicals has been increased by 17,037 titles, and now has entries for 117,085 articles. These are classified and indexed, and provide a readier guide to current articles than the published guides which usually cover only one year per volume. Readers find it increasingly helpful, and as it grows it becomes more and more self-sufficient for most needs.

### FINANCES

The budget for general operations, as approved by the Founder Societies and the Trustees, was $39,500, being $2950 less than for 1933. Of this amount $29,966.57 was provided through appropriations by the Founder Societies, as follows:

| | |
|---|---|
| American Society of Civil Engineers | $8,330.00 |
| American Institute of Mining and Metallurgical Engineers | 6,314.62 |
| American Society of Mechanical Engineers | 8,120.75 |
| American Institute of Electrical Engineers | 7,201.20 |

Actual expenditures were $40,002.79.

For work done during 1934, the Service Bureau received $7766.78, as compared with $6668.50 during 1933. Total expenses were $8538.67, as compared with $10,130 in 1933.

## Engineers' National Relief Fund Reports

A REPORT of the Engineers' National Relief Fund dated January 14, 1935, shows total receipts of $6845.57 from gifts. Loans made to January 14, 1935, amounted to $7156, of which $1345 has been repaid.

Ninety loans have been made to 74 engineers. Of these, 30 loans were to 24 members of the A.S.M.E. The individuals receiving loans represented 18 states. Six loans were made in Canada. Nine loans were made to seven non-members of the four founder societies.

The relief afforded by these loans has not only provided food, rent, and clothing, but in several cases, has made possible transportation to definite jobs and in two cases has saved engineers' homes from loss in foreclosure proceedings.

### E.N.R.F. ORGANIZED IN 1932

The Board of Direction of the Engineers' National Relief Fund was organized January 14, 1932, and since that time has held twenty meetings. The personnel of the Board is as

(*Continued on page 272*)

# "Everything is running all right"

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